

1 Introduction

The STM32W108 SimpleMAC (media access control) library provides a set of APIs to access the lower-MAC function of the STM32W108HB, STM32W108CB, STM32W108C8, STM32W108CZ and STM32W108CC microcontrollers (STM32W108xx). These devices integrate a 2.4 GHz IEEE 802.15.4-compliant transceiver featuring 16 channels and supporting 250 Kbps transfers. The SimpleMAC library is designed to run on all STM32W108 family devices. In addition, the SimpleMAC library will allow developing specific stacks based on the IEEE 802.15.4 standard.

This document provides information on:

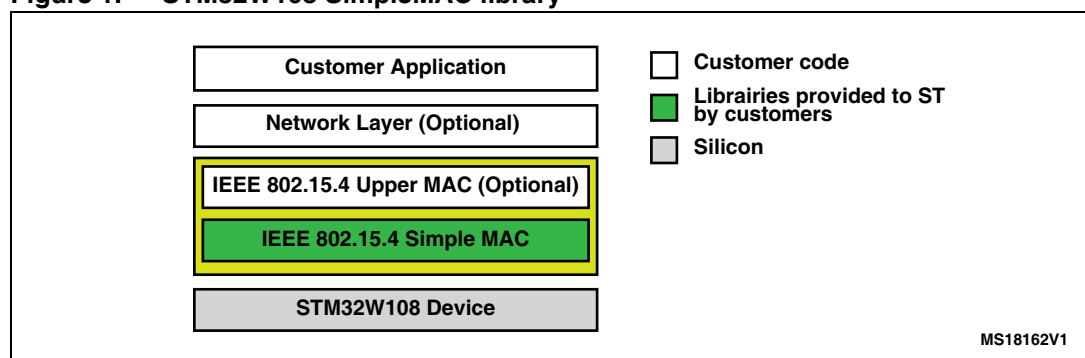
- IEEE 802.15.4 protocol
- STM32W108 SimpleMAC library features
- How to build and run STM32W108 SimpleMAC demonstration applications
- How to design an application using the STM32W108 SimpleMAC library APIs

Table 1 lists the microcontrollers and tools concerned by this user manual.

Table 1. Applicable products and tools

Type	Part numbers/product sub-classes
Microcontrollers	STM32W108xx
Evaluation tools to MCUs	STM32W-EXT STM32W-SK STM32W-RFCKIT

Figure 1. STM32W108 SimpleMAC library



Note: The term application board refers to the STM32W108xx boards delivered with all available STM32W108xx kits. This term is not used to refer to the STM32-Primer2 + MB850 platforms. For more information, visit the STM32W 32-bit RF microcontroller web pages at www.st.com/stm32w. These web pages provide full access to all STM32W108xx resources (kits, software packages and documents).

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2 IEEE 802.15.4 protocol

The IEEE 802.15.4 is a standard which specifies the physical layer (PHY) and the media access control (MAC) layer for low-rate wireless personal area networks (LR-WPANS).

The main features are as follows:

- Channel access via carrier sense multiple access with collision avoidance (CSMA-CA)
- Optional time slotting and network beaconing
- Message acknowledgement
- Multilevel security
- Suitable for long battery devices, with selectable latency to match different power requirements (sensors, remote monitoring, ...)

The IEEE 802.15.4 standard distinguishes between two types of devices:

- Full function devices (FFD)

Full function devices can be common nodes or coordinators of personal area networks (PANs). They can communicate with any device connected to the network and relay messages. FFD devices are suitable for any type of network topology.

- Reduced function devices (RFD)

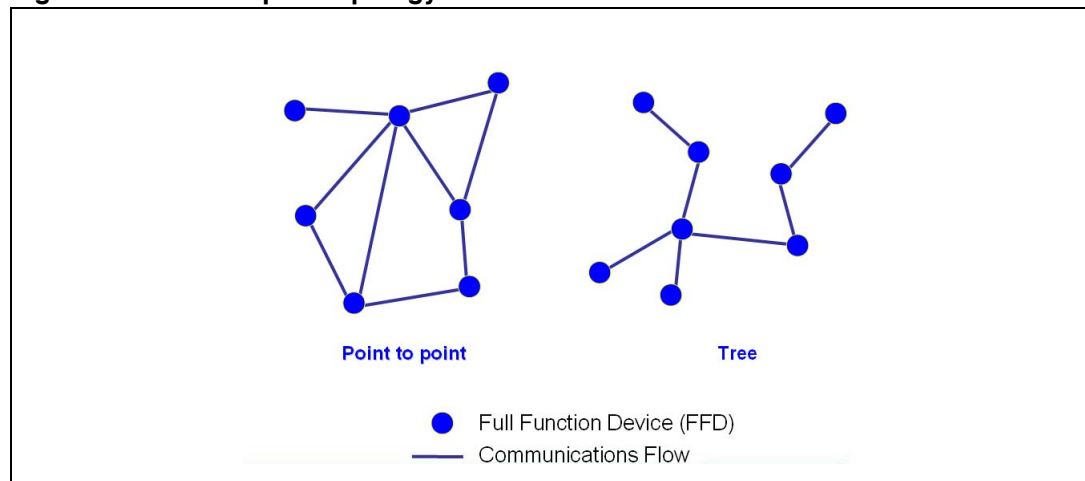
Reduced function devices are simple devices with limited resources and communication capabilities. They can only communicate with FFDs and can never act as coordinators. RFD devices are only suitable for star networks.

2.1 IEEE 802.15.4 networks

Two types of network topologies are supported:

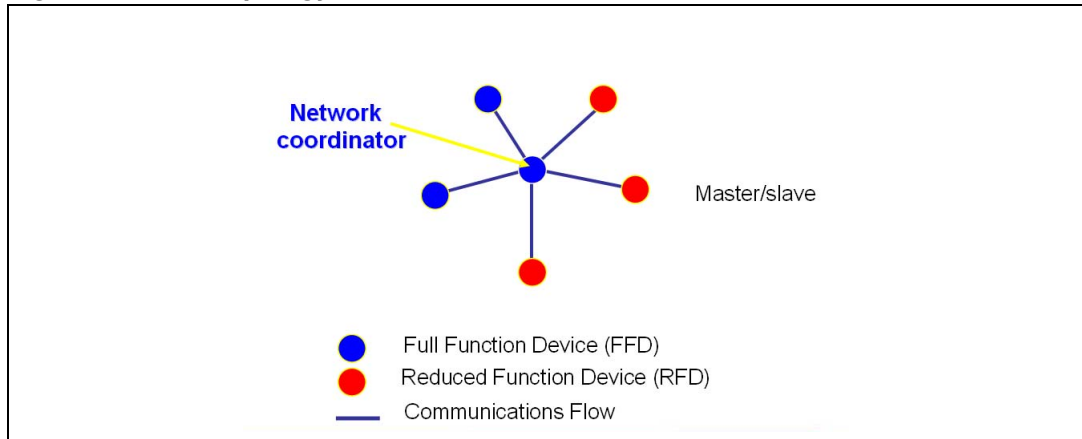
- Peer-to-peer networks where each device can communicate with any other device as long as they are in range of one another.

Figure 2. Peer-to-peer topology



- Star networks where communications are established between devices and a single central controller, called the PAN coordinator.

Figure 3. Star topology



2.2 IEEE 802.15.4 device addressing

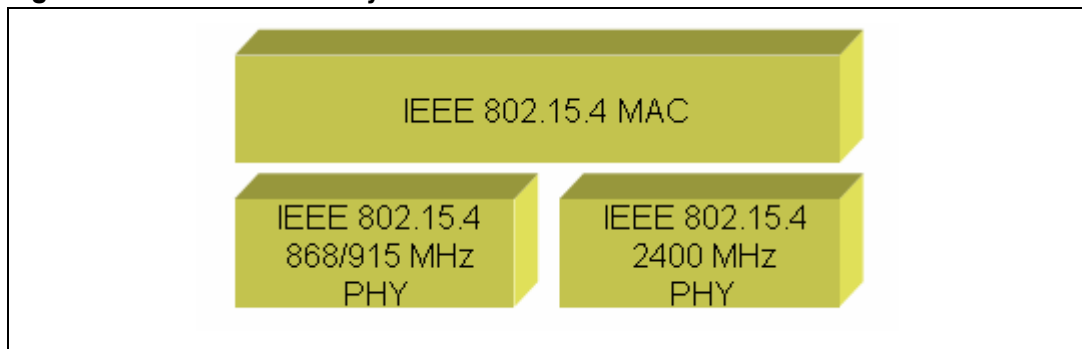
A unique PAN identifier is assigned to each independent PAN built on a channel.

All devices connected to the network have a unique 64-bit extended address. This address is used for direct communications through the PAN. A device can also use a short 16-bit address which is allocated by the PAN coordinator when the device is associated to the network.

2.3 PHY and MAC IEEE 802.15.4 protocol layers

Figure 4 shows the IEEE 802.15.4 MAC and PHY layers.

Figure 4. PHY and MAC layers



2.3.1 IEEE 802.15.4 PHY layer

The PHY layer manages the physical RF transceiver. It is also in charge of the following tasks:

- Activating and deactivating of the radio transceiver
- Energy detection for the current channel
- Indicating link quality for the received packets
- CCA for the CSMA-CA
- Selecting channel frequency
- Data transmission and reception

The standard specifies two PHY layers:

- 868/915 MHz direct sequence spread spectrum (DSSS) PHY
 - One 20 Kbps channel in the European 868 MHz band
 - Ten 40 Kbps channels in the 915 MHz ISM band (from 902 to 928 MHz)
- 2 450 MHz DSSS PHY supporting sixteen 250 Kbps channels in the 2.4 GHz band

Table 2. IEEE 802.15.4 PHY parameters

Parameter	2.4 GHz PHY	868/915 MHz PHY
Sensitivity @ 1% PER	-85 dBm	-92 dBm
Receiver maximum input level	-20 dBm	
Adjacent channel rejection	0 dB	
Alternate channel rejection	30 dB	
Output power (lowest maximum)	-3 dBm	
Transmit modulation accuracy	EVM < 35% for 1000 chips	
Number of channels	16	1/10
Channel spacing	5 MHz	Single-channel at 2 MHz
Transmission rates:		
Data rate	250 kbps	20/40 kbps
Symbol rate	62.5 ksymbols/s	20/40 ksymbols/s
Chip rate	2 Mchips/s	300/600 kchips/s
Chip modulation	O-QPSK with half-sine pulse shaping	BPSK with raised cosine pulse shaping

IEEE 802.15.4 PHY CCA

The following CCA modes are supported:

- CCA mode 1: energy above threshold (lowest)
- CCA mode 2: carrier sense (medium)
- CCA mode 3: carrier sense with energy above threshold (strongest)

IEEE 802.15.4 PHY link quality indication (LQI)

The LQI characterizes the strength and/or quality of a received packet. The measurement may be implemented using:

- Receiver energy detection
- Signal-to-noise ratio estimation

2.3.2 IEEE 802.15.4 MAC layer

The MAC layer is in charge of the following tasks:

- Generating network beacons for devices acting as PAN coordinators
- Synchronizing with the beacons
- Supporting PAN association and dissociation
- Supporting device security
- Using the CSMA-CA for channel access
- Managing the GTS mechanism
- Providing a reliable link between peer-to-peer MAC entities.

IEEE 802.15.4 MAC data transfer

The IEEE 802.15.4 MAC protocol supports two data transfer models that can be selected by the PAN coordinator:

- The non beacon-enabled mode, in which the MAC is simply ruled by unslotted CSMA-CA.
- The beacon enabled mode, in which beacons are periodically sent by the coordinator to synchronize the associated nodes and identify the PAN. Access to the channel is ruled by slotted CSMA-CA using the superframe structure.

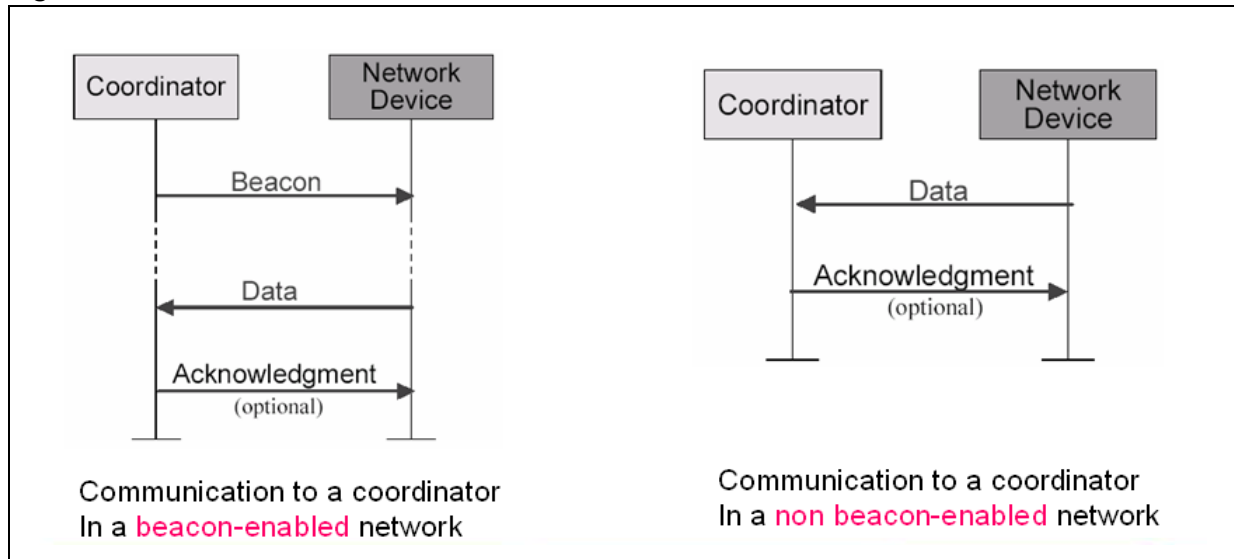
For detailed information about the IEEE 802.15.4 slotted/unslotted CSMA-CA and the superframe structure, refer to the related IEEE 802.15.4 standard specification.

IEEE 802.15.4 MAC device-to-coordinator data transfer

In beacon-enabled networks, the devices search for the beacon to synchronize with the superframe structure. They then transmit data using slotted CSMA-CA.

In non beacon-enabled networks, the devices simply transmit data using unslotted CSMA-CA.

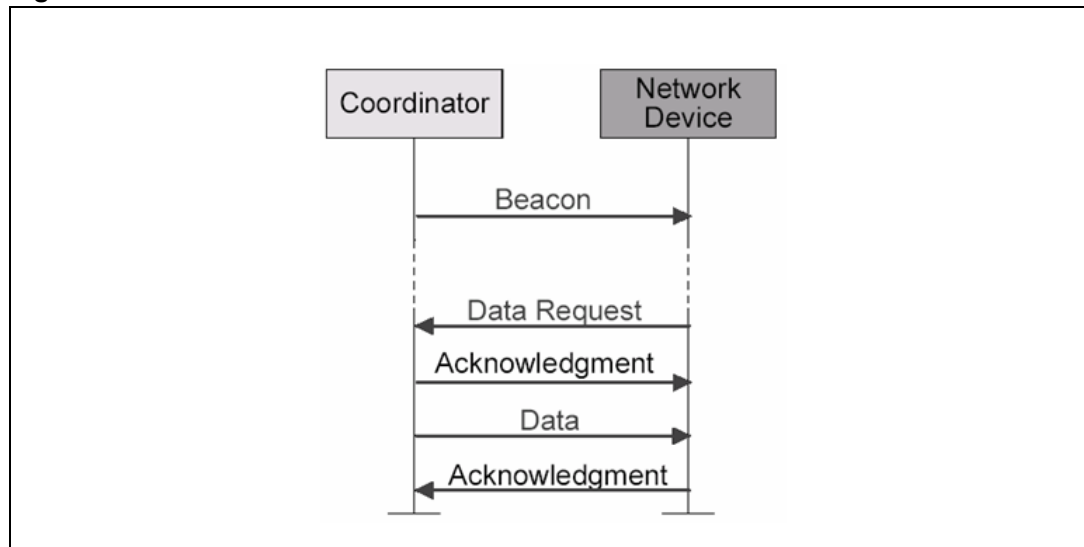
Figure 5. Device-to-coordinator communications



IEEE 802.15.4 MAC coordinator-to-device data transfer

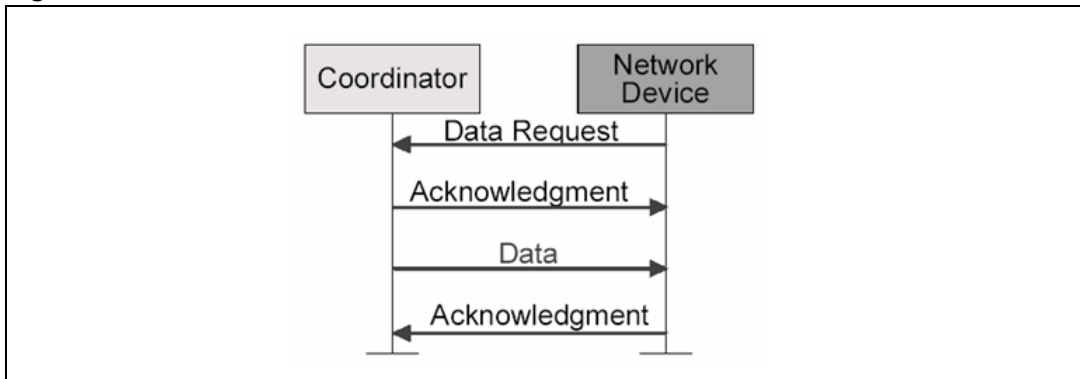
In beacon-enabled networks, the coordinator indicates in the beacon that data is pending. The device periodically listens to the beacons and transmits a data request MAC command using slotted CSMA-CA if necessary.

Figure 6. Coordinator-to-device communications in beacon-enabled networks



In non beacon-enabled networks, devices transmit a data request MAC command using unslotted CSMA-CA. If a coordinator data transmission is pending, the coordinator transmits a data frame using unslotted CSMA-CA. Otherwise, the coordinator transmits a data frame containing a zero-length payload. Refer to [IEEE 802.15.4 general MAC frame format](#) for a description of the MAC frame.

Figure 7. Coordinator-to-device communications in non beacon-enabled networks



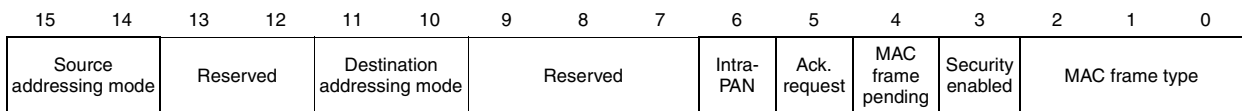
IEEE 802.15.4 general MAC frame format

The MAC frame is composed of a MAC header (MHR), a MAC payload, and a MAC footer (MFR). The MHR is composed of fixed fields. The address fields are optional.

Table 3. General MAC frame format

2 bytes	1 byte	0/2 bytes	0/2/8 bytes	0/2 bytes	0/2/8 bytes	Variable	2 bytes
Frame control field (FCF)	Sequence number	Destination PAN identifier	Destination address	Source PAN identifier	Source address	Frame payload	FCS
		Addressing fields					
MHR						MAC payload	MFR

The MAC frame control field (FCF) has the following structure:



Bits [15:14] Source addressing mode

- 00: PAN identifier and address field are not present.
- 01: reserved
- 10: Address field contains a 16-bit short address.
- 11: Address field contains a 64-bit extended address.

Bits [12:13] Reserved

Bits [11:10] Destination addressing mode

- 00: PAN identifier and address field are not present.
- 01: reserved
- 10: Address field contains a 16-bit short address.
- 11: Address field contains a 64-bit extended address.

Bits [7:9] Reserved

Bit 6 **Intra-PAN**

- 1: frame to be sent within same PAN
- 0: frame to be sent to another PAN

Bit 5 **Acknowledge request**

- 1: device sends an acknowledgment frame when it receives a valid frame
- 0: device does not send an acknowledgment frame when it receives a valid frame

Bit 4 **MAC frame pending**

- 1: sender device has additional data to send to the receiver
- 0: sender device does not have any more data for the receiver

Bit 3 **Security enabled**

- 1: frame is cryptographically protected by the MAC layer
- 0: frame is not cryptographically protected by the MAC layer

Bits [2:0] **MAC frame type**

- 000: Beacon
- 001: Data
- 010: Ack
- 011: MAC command
- 100: Reserved
- 111: Reserved

IEEE 802.15.4 PHY frame format

Table 4 shows the PHY frame structure.

Table 4. PHY frame format

4 bytes	1 byte	1 byte		Variable
Preamble	SFD	Frame length (7 bits)	Reserved (1 bit)	PHY payload field (PSDU)
SHR		PHR		PHY payload

- The preamble field is used by the transceiver to perform chip and symbol synchronization with an incoming message. The preamble is composed of 32 binary zeros.
- The SFD field (start-of-frame delimiter) is an 8-bit field indicating the end of the synchronization preamble and the start of the packet data. The SFD must be equal to 10100111b.
- The frame length field is 7-bit long. It specifies the total number of bytes contained in the PHY payload field (PSDU). Its value ranges from 0 to 127.
- The PHY payload field (PSDU) contains the MAC frame.

For more details about the PHY and MAC frames, refer to the IEEE 802.15.4 standard specification.

3 STM32W108 SimpleMAC library overview

This section describes the STM32W108 SimpleMAC library features:

- IEEE 802.15.4 PHY features supported by the library
- IEEE 802.15.4 MAC features supported by the library
- SimpleMAC library APIs naming conventions and classes.

3.1 IEEE 802.15.4 PHY layer supported features

The SimpleMAC library supports the following IEEE 802.15.4 PHY features:

- Radio channel selection on 2.4 GHz band
- Radio calibration
- Transmission power control
- Boost mode control
- Selection of alternate transmission path for external power amplifier
- Radio sleep and wakeup control
- Time stamp of received and transmitted packets
- LQI and RSSI for received packets
- Transmit single carrier frequency (diagnostic function)
- Transmit continuous stream of random symbols (diagnostic function)
- Automatic seeding pseudo random number generator using hardware random number source

3.2 IEEE 802.15.4 MAC supported features

The SimpleMAC library supports the following IEEE 802.15.4 MAC features:

- Transmit functions
 - Unslotted CSMA transmit support including CCA
 - Backoff periods determined by pseudo random number generator
 - CRC generation and CRC data insertion into packets
 - Automatic reception and verification of acknowledgement
- Receive functions
 - Packet reception with hardware filtering, correlator error and CRC checking
 - Ability to set node addresses and PAN identifier (for receive filtering only)
 - Hardware filters fully exposed
 - Automatic transmission of acknowledgement with software control over frame pending indication
 - Promiscuous mode
 - Ability to enable/disable receivers

3.3 SimpleMAC library API naming conventions

The following naming conventions are used:

- **General prefix**
All SimpleMAC APIs are prefixed with “ST_” followed by the general API family (e.g. Radio, AES).
- **Callback suffix**
The functions which are implemented in the application and called from the SimpleMAC library are suffixed with “Callback”.
- **ISR callback suffix**
The functions which are implemented in the application and called from the SimpleMAC library in interrupt context are suffixed with “IsrCallback”.
- **ISR suffix**
The functions which are implemented in the SimpleMAC library and must be called by the application in response to hardware events are suffixed with “Isr”.

3.4 SimpleMAC Library APIs classes

The following API classes are supported:

- Radio power state control APIs which control the overall radio initialization and power state.
- Radio channel APIs which control channel selection and calibration.
- Radio transmit APIs which control the transmission of packets.
- Radio receive APIs which control the reception of packets.
- Radio cryptography APIs which provide an interface to the hardware AES coprocessor.
- Radio MAC timer APIs to interface with the MAC timer.
- Radio miscellaneous APIs which perform MAC diagnostic and configuration.

For a detailed description of the SimpleMAC library APIs, refer to the STM32W108 SimpleMAC Library APIs documentation.

4 STM32W108 SimpleMAC demonstration applications

Four simpleMAC demonstration applications are delivered within the SimpleMAC software library package which is available from the STM32W 32-bit RF microcontroller web pages at www.st.com/stm32w:

- SimpleMAC sample demonstration applications (sun and planet roles)
- SimpleMAC talk demonstration application
- SimpleMAC mouse demonstration application
- SimpleMAC OTA bootloader demonstration application
- SimpleMAC nodetest application

The demonstration applications designed to run on an application board may require a serial communication interface.

The following subsections provide a description of the building and running steps of the demonstration applications using the IAR projects delivered within the SimpleMAC software library package as a reference. The available workspaces provide reference examples for the STM32W108CC boards.

4.1 SimpleMAC sample demonstration application

This is an example of an RF application that shows an 802.15.4 star topology using the STM32W108 microcontroller.

4.1.1 IAR project

To use the project with IAR Embedded Workbench for ARM, follow the instructions below:

1. Open the Embedded Workbench for ARM.
2. From the **File > Open > Workspace** menu, open the related IAR workspace.
3. Select the configuration that you want to build.
4. Select **Project > Rebuild All** to recompile and link the entire application.
5. To launch a debug session, connect the IAR Jlink to the JTAG connector (P1) in your board.
6. Select **Project > Download and Debug**. The related binary image is downloaded into the STM32W108CC Flash memory and the interactive debug session is started.
7. Connect the application board to a PC USB port. Open a hyperterminal on the corresponding USB virtual COMx port with the configuration, as described in [Section 4.1.4: Serial I/O](#).

4.1.2 Jumper settings

Table 5. Jumper settings

Jumper name	All configurations
JP1, if available	Irrelevant
P1, if available	1-2 (battery) 5-6 (USB)

4.1.3 Boards supported

Table 6. Boards supported

Board name	Board revision	STM32W108xB	STM32W108CC	Sun	Planet
Primer2 + MB850 A	A	X	NA	X	-
MB851	A,B,C	X	NA	X	X
	D	NA	X	X	X
MB954	A,B	X	NA	X	X
	C	NA	X	X	X
MB950A + MB953	MB953A	X	NA	X	X
	MB953B	NA	X	X	X
MB951	A	X	NA	X	X
	B	NA	X	X	X

X = supported

- = not supported

NA = not applicable

4.1.4 Serial I/O

The application listens for commands sent over the serial port. The serial port configuration is:

Table 7. Serial I/O

Parameter name	Value	Unit
Baud rate	15200	bit/sec
Data bits	8	bit
Parity	None	bit
Stop bits	1	bit

4.1.5 LED description

Table 8. LED description

LED name	STM32W108xB_SUN	STM32W108xB_PLANET
D1	Not used	Not used
D3	Not used	– On when joined a network – Off when not joined

4.1.6 Button description

Table 9. Button description

Button name	STM32W108xB_SUN	STM32W108xB_PLANET
S1	Not used	Join network
S2	If available	Not used
S3	If available	Not used
S4	If available	Not used
S5	If available	Not used

4.1.7 Usage

This demonstration represents an Application Framework which sets up a basic star topology and supports parent and child roles. To prevent name collisions with other software, applications, and implementations, the parent role is called "sun" and the child role is called "planet". These roles are implemented using specific definitions: SUN_ROLE and PLANET_ROLE.

Executing the form command on a node loaded with the sun image provokes the node to form a network. Executing the form command, on a node loaded with the planet image, provokes the node to join the network formed by the sun node. Executing the leave command provokes each node to leave the network. There cannot be multiple suns on the same PAN ID.

The sample applications demonstrate:

- Management of a simple direct transmission queue
- Management of a simple indirect transmit queue including interaction with the receive ISR, in order to handle the setting of the ACK frame pending bit, in response to a data poll
- Sleepy planets automatically send the radio to sleep when there is no more data to transmit
- Retry of packet on ACK failure
- Active search for a sun implemented as simple blocking code
- Energy search for a channel with low activity implemented as simple blocking code
- Capture of transmit SFD time and insertion of time value into packet payload.
- Conversion of correlator error count to LQI
- Planet deep sleeping

Note: All references to "sleep" and "sleepy" refer to deep sleep operations.

4.1.8 Serial commands supported

Table 10. Serial commands supported

Command	Description	STM32W108xB_SUN	STM32W108xB_PLANET
i	Display status information	X	X
f	Form a network	X	-
j	Join a network	-	X
l	Leave a network	X	X
s	Send data	X	X
c	Clear indirect transmit queue	X	-
p	Poll for data	-	X
r	Adjust send/poll rates	X	X
t	Display the planet table	-	X
o	Enter OTA bootloader mode	X	X
u	Enter Uart bootloader mode	X	X
?	Display this help menu	X	X

X = supported

- = not supported

Note: All commands are invoked as a single character.

Table 11. Detailed command description

Command	Description
i	<p>Display status information displays the status of the node including information such as:</p> <ul style="list-style-type: none"> – Network role – Radio on/off state – In or out of a network – Channel – Power – EUI64 – PAN ID – Node ID – Send rate – Poll rate
f	<p>Form a network can only be executed while not already in a network. To form the network, the node first initializes all persistent states then loops over all channels searching for the channel with the lowest energy. The node dwells on each channel taking multiple energy readings and records the highest energy level seen on every channel. After obtaining a maximum energy reading for each channel, the node selects the channel with the lowest maximum energy reading and configures itself for that channel. The node then assigns itself a random PAN ID and assigns itself the short address (node ID) 0x0000.</p>
j	<p>Join a network can only be executed while not already in a network. To join the network, the node first initializes all persistent states then loops over all channels searching for a channel with a sun. On each channel, the node transmits a sun search broadcast packet and then waits for 200 ms for a sun available response. If the node does not receive a sun available broadcast response after 200 ms, it moves on to the next channel. If the node never receives a sun available response or cannot complete the join process on any channel, the node indicates this fact to the user and the user must invoke the join network command to try again.</p> <p>The sun only sends the sun available response if there is room in the sun's planet table. If the node does receive a sun available response, the response includes the sun's PAN ID as the source PAN ID. If the node receives more than one sun available response, the node tries to join the first response it receives.</p> <p>Multiple suns on the same PAN ID are not valid, and there is no collision detection for this situation. The planet sends a join request unicast packet using long addressing and the sun's PAN ID. When the sun receives the join request, the sun attempts to place to the planet in its planet table. The planet table is a fixed size. If there is no room in the planet table, the sun responds with a join denied unicast packet. If there is room in the planet table, the sun allocates a new short ID to the planet, puts the planet in its planet table, and responds with a join accepted unicast packet. There is no error detection if the join process fails before the join accepted or denied packet has been received.</p> <p>The sun does not remove planets from its planet table unless the planet specifically sends a leaving network packet.</p>

Table 11. Detailed command description (continued)

Command	Description
l	Leave a network can only be executed while already in a network. On sun nodes, this command simply clears out key persistent state indicating it is no longer active in a network. On planet nodes, this command sends a message to the sun indicating that it is leaving the network. After sending the leaving message, key persistent state is cleared out indicating it is no longer active in a network. The sun does not acknowledge the leave message. After the leave is complete, on either a sun or planet, forming a new network or joining an existing network is now allowed.
s	Send data can only be executed while already in a network. Send a single unicast message. Automatically sending is controlled with the command "r - Adjust send/poll rates". On planet nodes, a unicast message is placed on the direct transmission queue and sent directly to the sun. On sun nodes, the user is first presented a table of all planet nodes that are active in the sun's planet table. The user must then select the node that the unicast message will be sent to. The unicast message is placed on the indirect transmission queue. The message will stay on the queue until that destination node polls for messages, at which point the sun will transmit the message to the planet. These unicast messages use short addresses for both the destination and source. The payload includes the 16-bit VDD_PADS measurement as provided by the related API. Additionally, the 20-bit (3 byte) transmit SFD time of the packet being transmitted is added to the end of the packet payload while the packet is being transmitted. The MSB of the 3-byte SFD time is set last, indicating to the receiver that the SFD was correctly placed into the packet.
c	Clear indirect transmit queue can only be executed while already in a network. It forcefully clears the indirect transmit queue of all packets that are not already in flight. This command is necessary due to: the limited size of the indirect transmit queue, the persistence of the packets in the queue, and the fact that a planet with pending data could disappear from the network and never poll for its pending data.
p	Poll for data can only be executed while already in a network and this command is ineffectual on sun nodes. Poll once. Automatically polling is controlled with the command "r - Adjust send/poll rates". Non-sleepy planets are allowed to poll but, since the sun will not queue up indirect transmission for non-sleepy planets, the poll will never result in receiving messages. This command sends a short unicast poll packet to the sun. If the sun has data pending for the polling planet, the sun sets the frame pending bit in the MAC ACK. When the planet receives the MAC ACK, it observes the frame pending bit. If the frame pending bit is not set, the planet immediately goes back to sleep. If the frame pending bit is set, the planet stays awake for 200 ms with receiver on waiting for the sun to transmit the message. After 200 ms, the planet goes back to sleep.

Table 11. Detailed command description (continued)

Command	Description
r	<p>Adjust send/poll rates can only be executed while already in a network. Sending data at a regular rate is valid on both sun and planets, but polling at a regular rate is only valid on sleepy planets. The rate command implements a sub menu to independently control automatic/periodic sends and polls. Rates are chosen as the number of quarter-seconds between the events. A rate of zero will turn off that event. The send data command performs a single send whereas the rate command enables automatic and regular sending. The poll command performs a single poll whereas the rate command enables automatic and regular polling. It is valid to issue a send command while the send rate is greater than zero, and it is valid to issue a poll command while the poll rate is greater than zero. Manually issuing a send or poll command while the rates are greater than zero will simply add those commands to the queue and not disrupt rate controlled operations. This command implements a series of sub menus which configure:</p> <ul style="list-style-type: none"> – which planets get regular messages from the sun – the rate at which the sun sends regular messages to the planet – the rate at which the planet sends regular messages to the sun – the rate at which the planet polls for messages from the sun
t	<p>Display the planet table on sun nodes command displays the entire planet table. Each entry in the table indicates:</p> <ul style="list-style-type: none"> – whether or not the entry is active, which means the planet is still joined the sun – whether or not there is pending data in the indirect transmission queue for that planet – the short address (node ID) of that planet – the long address (EUI64) of that planet
o	<p>Enter OTA bootloader mode activates the IAP bootloader in Over the Air mode. The user is requested to provide the application binary image over the air (see the <code>stm32w_flasher -i rf</code> option or the <code>bootloader_demo</code> application example).</p>
u	<p>Enter Uart bootloader mode activates the IAP bootloader in Uart mode. The user is requested to provide the application binary image through the uart interface (see the <code>stm32w_flasher -b</code> option).</p>
?	<p>Display help menu shows the top level commands and their associated single character command.</p>

Notes

- Packet Reception:** Commands print status information while the commands are operating. For example, when forming a network, the form command displays the selected channel, the channel energy, and the chosen PAN ID. For received packets, only data (unicast) messages are printed. These messages are the result of the send command or the rate command. When a node receives a data message, it prints:
- the short address of the sender (hex number)
 - VDD_PADS, stored in the message payload (decimal number)
 - the 20-bit SFD time from the receiver (hex number)
 - the 20-bit SFD time from the transmitter, stored in the message payload (hex number)
 - the RSSI (decimal number)
 - the LQI (hex number)
- Deepsleep Behavior:** When a node is not connected to a network or is a planet, the node will immediately begin deep sleep operations. The user is also informed that the node is entering deepsleep operations, and the command interface is dormant. Wakeup can occur due to debugger activity, periodic events, or UART activity. If the node wakes up due to the debugger or periodic events, the node will inform the user that it is awake and return to deep sleep as soon as possible. In this situation, the command interface stays dormant. To wakeup from deepsleep and reactivate the command interface, the user must send a character on the UART. When the node wakes up from UART activity, the user will be prompted that the node is awake and that the command interface is capable of accepting a command. The node will stay awake with the command interface active until the user executes any command. After a command is executed and completed, the node will return to deep sleep.
- Periodic Events:** In addition to constantly driving network activity in the main loop, the application performs periodic and scheduled events. The timing of two of these periodic events, send and poll, is controlled via the rate command. In addition to the send and poll events, there is a periodic maintenance event that occurs every 60 seconds and performs tasks that are critical to keeping the chip in optimal operating conditions. The maintenance event:
- checks the radio and invokes calibration, if necessary
 - checks the 24 MHz crystal bias trim and adjusts the trim, if necessary
 - checks the GPIO pad drive strength and adjusts the drive strength, if necessary
- Primer2 sun application:**
- When a planet device joins the network, a green box with the assigned node ID is displayed on the LCD (up to 5 planets).
 - The Primer2 sun application displays the received VDD_PADS value from each planet (in mV)
 - The "Send data" command is not supported through the Primer2 LCD menu
 - The Primer2 sun application doesn't display the "poll" message coming from a planet
 - When interacting with the Primer2 sun application, it is recommended to keep the planet send rate to a value not lower than the default set value.

Note: *STM32-Primer2 with MB850 is only available with the STM32W108B-SK kit.*

You need to use at least two boards to perform the demonstration. Follow the instructions:

1. Load the one board with the sun role application.
2. Load the remaining boards with the planet role application.
3. Open a terminal on the sun board and type f.
4. Push the S1 button on all the planet role boards in sequence, waiting for LED D3 to switch on indicating a successful connection to the sun.
5. All the planets should have LED D3 on, and you should now see messages coming from planets to the sun.

4.1.9 Running the sample demonstration application on the STM32-Primer2 with an MB850 board

The STM32-Primer2 with MB850 sun application supports some of the sample demonstration events and input commands described in [Section 4.1](#) through the STM32-Primer2 interface resources (LCD, joystick with button, touch screen).

These events and commands are mapped to graphic events displayed on the STM32-Primer2 LCD, as shown below.

Figure 8. Star network created by sun **Figure 9. Planet associated to sun** **Figure 10. Data sent from planet to sun**

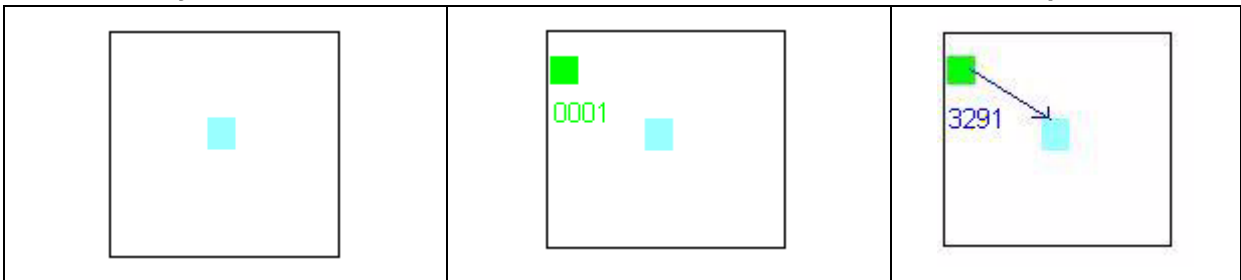
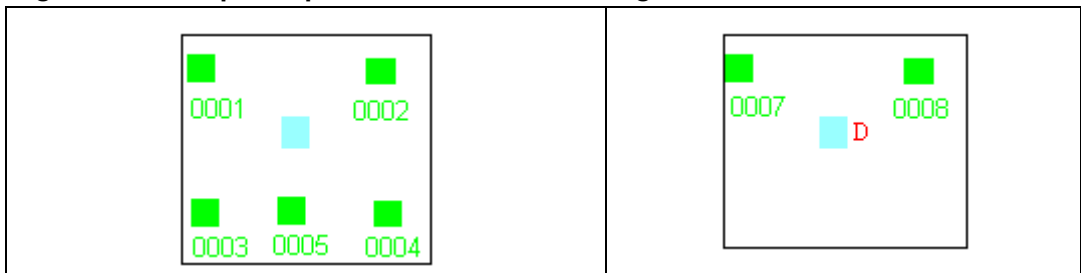


Figure 11. Sun plus 5 planets **Figure 12. Network down**



The scenario shown in [Figure 8](#) is obtained by selecting **SM SUN** from the LCD menu. The input commands listed in [Table 12](#) can then be issued by selecting the corresponding item from the related LCD menu.

Table 12. STM32-Primer2 SM SUN menu versus input commands

Menu items	Description
Planet table	Displays the list of planets
Leave network	Quits the network
Sun infos	Displays the sun node status and information.

Note:

The STM32-Primer2 with MB850 is only available with the STM32W108B-SK kit.

The STM32-Primer2 with MB850 sun application also supports an interface communication channel through a virtual USB COM. Connect a mini USB cable to the bottom-right side of the STM32-Primer2 and to a PC USB port, and configure the related hyperterminal to 115 200 bps, 8-bits, no parity and flow control, and one stop bit.

The STM32-Primer2 sun application displays the V_{DD} values (in mV) received from each application board planet.

The Send data command is not supported by the STM32-Primer2 LCD menu.

The STM32-Primer2 sun application does not display data polled from a planet.

4.2 SimpleMAC PC sun GUI application

A PC applet targeting the SimpleMAC sun application is available.

The main functions of the SimpleMAC sun PC applet are:

- Sun node forming an IEEE 802.15.4 network
- Giving all information about the sun node (channel, pan ID, node ID,, eui64, tx power, ..)
- Handling planet nodes joining the network
- Handling planet nodes leaving the network once
- Sun node exiting the network
- Sun node receiving data from each joined planet node

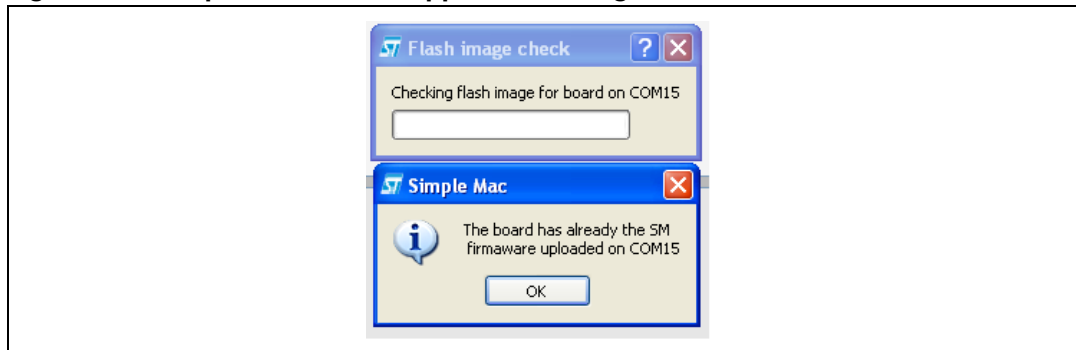
4.2.1 Run the SimpleMAC sun PC applet

The application board is automatically configured when launching the SimpleMAC sun PC applet.

To run the SimpleMAC sun PC applet on an application board, the following steps are required:

1. Connect the application board to the PC using a mini USB cable with P2 fitted in position 5-6 (power from USB). A virtual COM port should appear in the Windows Device Manager (or connect the USB dongle directly to a PC USB port).
2. From Windows, launch the SimpleMAC sun Application.exe PC applet. A PC applet GUI appears.
3. Select the serial port matching the port assigned by the Windows Device Manager. If the firmware on the application board is not present, the application uploads the firmware through the serial port.

Figure 13. SimpleMAC sun PC applet flash image check




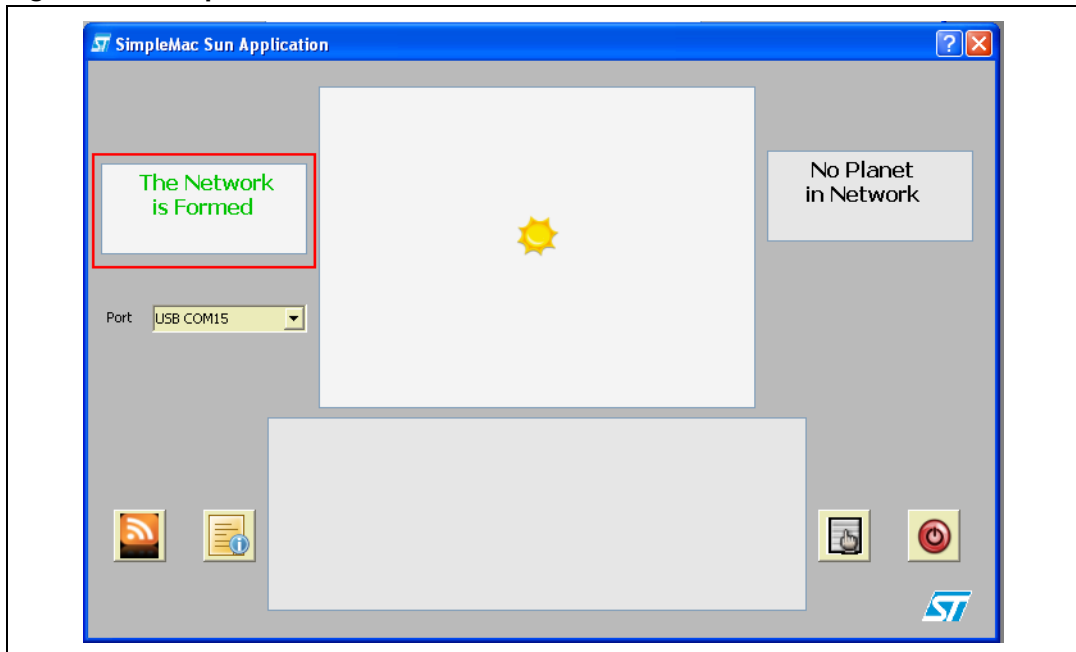



4. Push the button  to allow the sun node to form a network. If everything is done properly, you get the following picture:

Figure 14. SimpleMAC sun node forms an IEEE 802.15.4 network



The SimpleMAC sun PC applet also offers these command options:

Table 13. SimpleMAC sun PC applet command options

Command	Description
	Displays all information about the sun node
	Displays a table giving information about planets
	Allows the sun node to leave the network

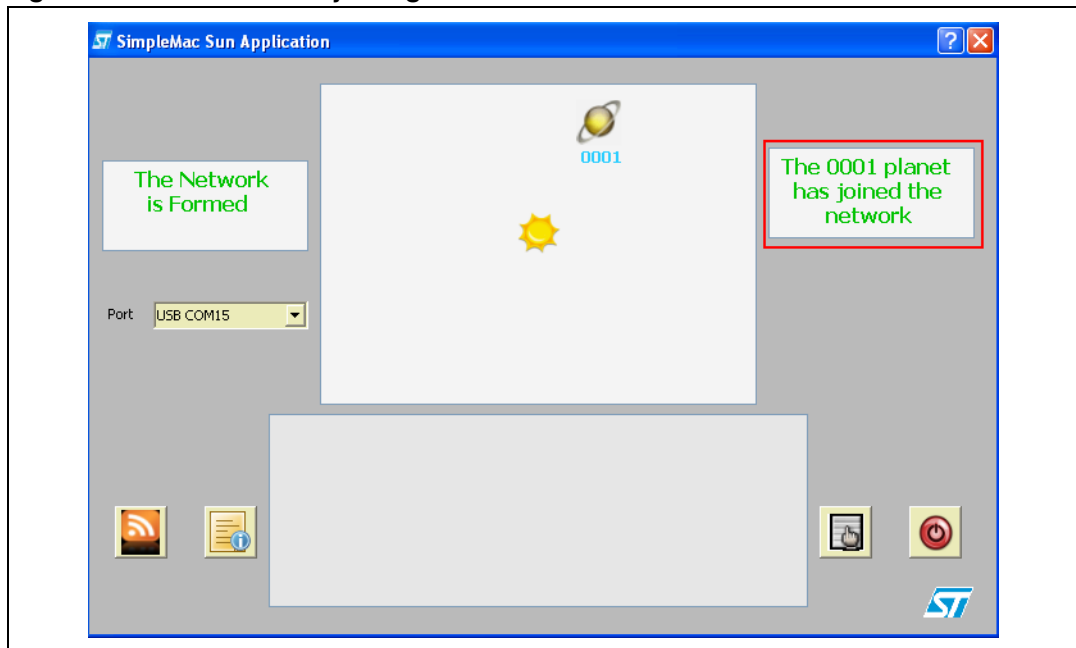
4.2.2 Build, download and run the sample planet application on the application board

To build, download and run the sample planet application on an application board, use the related IAR project provided within the SimpleMAC software library package following the instructions described in [Section 3.3](#).

4.2.3 Set up a star network

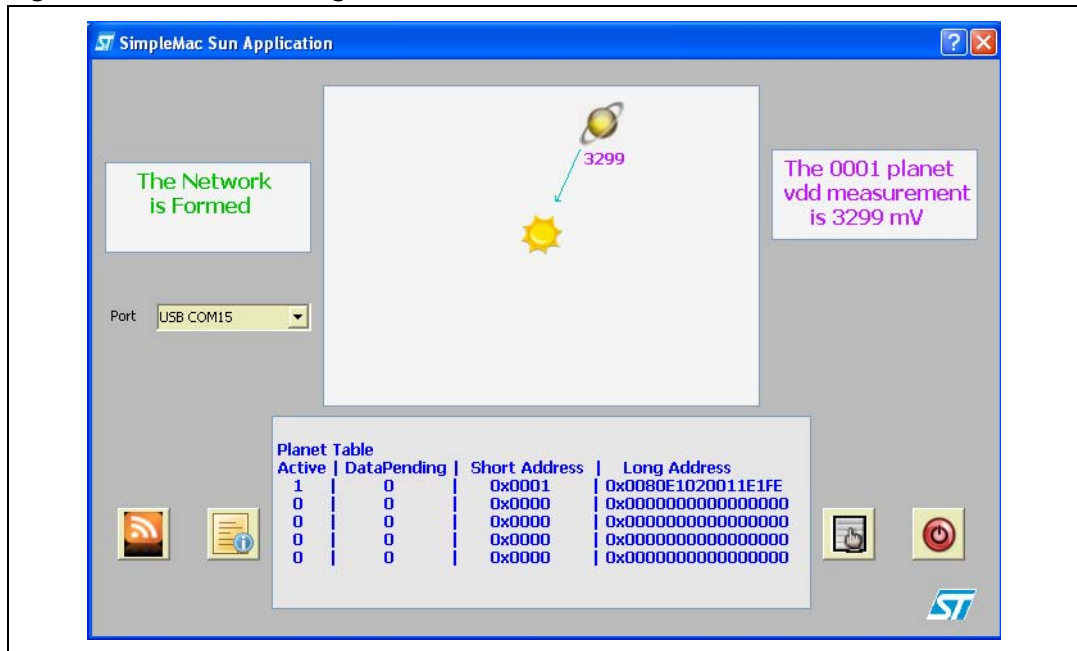
On the planet node, press button S1 to join the network formed by the STM32W108xx sun node. Once joined, the planet node is displayed on the SimpleMAC sun PC applet.

Figure 15. Planet device joining the network



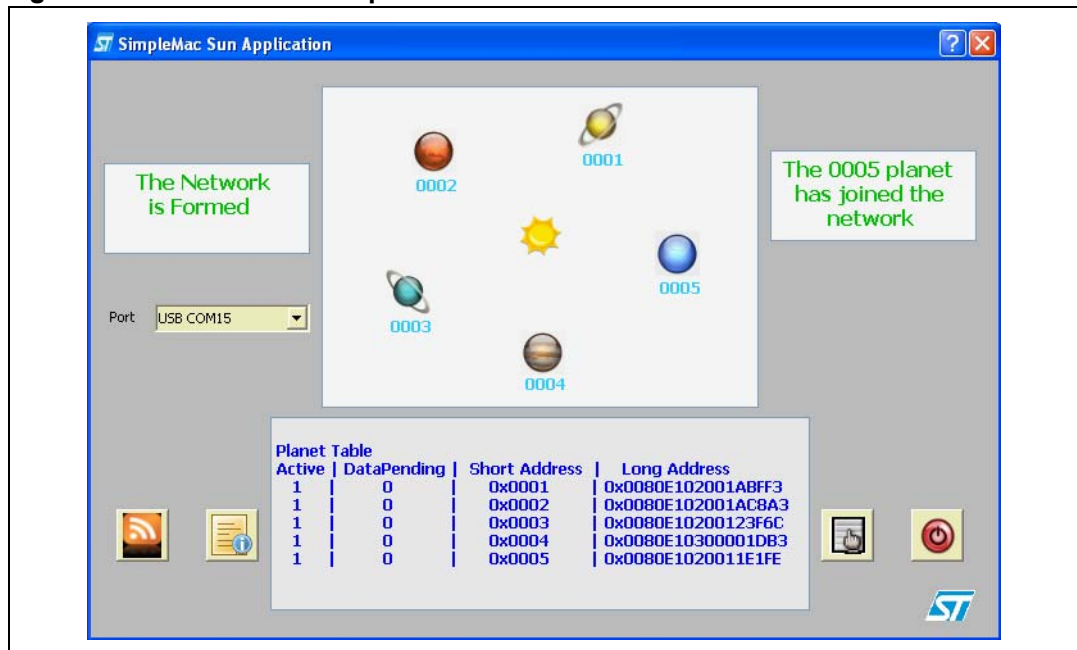
When a planet device sends data to the sun device (at a periodic rate), a line connecting the transmitting planet to the sun is displayed on the SimpleMAC sun PC applet, as well as the sent application board VDD_PADS value (in mV).

Figure 16. Planet sending data to the sun



This identifies which planet is in transmission mode, if there is more than one planet device (up to 5 planets supported by the SimpleMAC sun PC applet)

Figure 17. Sun node with 5 planets



4.3 SimpleMAC talk demonstration application

This is an example of an RF application that demonstrates point-to-point 802.15.4 wireless communication using the STM32W108 microcontroller.

4.3.1 IAR project

Follow these steps to use the project with IAR Embedded Workbench for ARM:

1. Open the Embedded Workbench for ARM.
2. From the **File > Open > Workspace** menu, open the related IAR workspace.
3. Select the configuration that you want to build.
4. Select **Project > Rebuild All**. This will recompile and link the entire application.
5. To launch a debug session, connect the IAR Jlink to the JTAG connector (P1) on the board.
6. Select **Project > Download and Debug**. The related binary image is downloaded into the STM32W108CC Flash memory and interactive debug session is started.
7. Connect the application board to a PC USB port. Open a hyperterminal on the corresponding USB virtual COMx port with the configuration as described in [Section 4.3.4: Serial I/O](#).

4.3.2 Jumper settings

Table 14. Jumper settings

Jumper name	STM32W108xB
JP1, if available	Irrelevant
P1, if available	1-2 (battery) 5-6 (USB)

4.3.3 Boards supported

Table 15. Boards supported

Board name	Board revision	STM32W108xB	STM32W108CC	Talk
Primer2 + MB850 A	A	X	NA	-
MB851	A,B,C	X	NA	X
	D	NA	X	X
MB954	A,B	X	NA	X
	C	NA	X	X
MB950A + MB953	MB953A	X	NA	X
	MB953B	NA	X	X
MB951	A	X	NA	X
	B	NA	X	X

X = supported

- = not supported

NA = not applicable

4.3.4 Serial I/O

The application listens for keys typed in one node and sends them to the remote node. The remote node listens for RF messages, which it outputs to the serial port. Everything typed in one node is visible to the other node and vice versa.

Table 16. Serial I/O

Parameter name	Value	Unit
Baud rate	15200	bit/sec
Data bits	8	bit
Parity	None	bit
Stop bits	1	bit

4.3.5 LED description

Table 17. LED description

LED name	Event	STM32W108xB
D1	Button press	<ul style="list-style-type: none"> – On when a button is pressed – Off when the message corresponding to the button press is sent
D3	Button press	None
D1	RF message received	See Button description
D3	RF message received	See Button description
D1+D3	Error in transmission	Flash together for one second

4.3.6 Button description

Button presses on the board result in sending an RF message to the other board. The action taken by the other board is described in [Table 18](#).

Table 18. Button description

Button name	STM32W108xB
S1	Toggle LED D1 in the remote node
S2	Toggle LED D3 in the remote node
S3	Toggle LEDs D1 and D3 in the remote node
S4	Blinks LED D1 for a few seconds in the remote node
S5	Blinks LED D3 for a few seconds in the remote node

4.3.7 Usage

This demonstration illustrates two use cases:

- RS232 cable replacement
This scenario illustrates an existing point-to-point communication based on a wired RS232 connection, which is replaced by 802.15.4 2.4GHz RF link.
- Simple remote control implementation
This scenario illustrates a button push on one board (remote control), resulting in LED activities on the other board (actuator).

The demonstration requires two boards. Follow the instructions:

1. Load the two boards with the talk application.
2. Open a terminal on both boards so you can see the keystrokes sent from one terminal to the other. This is an RS232 cable replacement demonstration.
3. Push any button on one board and observe the corresponding action on the other board LEDs. This is a simple remote control implementation.

Note: **Notes and limitations**

You cannot use more than two nodes with a talk application in the same radio range because RF conflicts will arise.

When pressing a button on the Talk Application Board 1, LED D1 is turned on indicating a packet is going to be sent.

If something is wrong with the current RF communication (packet transmission failed or no acknowledgment received from the Talk Application Board 2), pressing a button on the Talk Application Board 1 makes the Talk Application Board 1 LEDs (D1 and D3) blink for a few seconds.

4.4 SimpleMAC mouse demonstration application

This demo application shows how to implement an RF mouse based on MEMS movement.

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4.4.1 IAR projects

An IAR workspace is also provided for the SimpleMAC MEMS mouse demonstration application.

Follow these steps to use the project with IAR Embedded Workbench for ARM:

1. Open the Embedded Workbench for ARM.
2. From the **File > Open > Workspace** menu, open the related IAR workspace.
3. Select the configuration you want to build.
4. Select **Project > Rebuild All**. This will recompile and link the entire application.
5. To launch a debug session, connect the IAR Jlink to JTAG connector (P1) on your board.
6. Select **Project > Download and Debug**. The related binary image is downloaded into the STM32W108CC Flash memory, and an interactive debug session is started.
7. Connect the application board to a PC USB port. Open a hyperterminal on the corresponding USB virtual COMx port, with the configuration as described in [Section 4.4.4: Serial I/O](#).

4.4.2 Jumper settings

Table 19. Jumper settings

Jumper name	STM32W108xB_TX	STM32W108xB_RX
JP1, if available	Fitted	Irrelevant
P1, if available	2 (battery) 5-6 (USB)	5-6

4.4.3 Boards supported

Table 20. Boards supported

Board name	Board revision	STM32W108x B	STM32W108 CC	TX	RX
Primer2 + MB850 A	A	X	NA	-	-
MB851	A,B	X	NA	X	-
	C	X	X	X	X
	D	NA	X	X	X
MB954	A	X	NA	X	-
	B	X	NA	X	X
	C	NA	X	X	X
MB950A + MB953	MB953A	X	NA	X	X
	MB953B	NA	X	X	X
MB951	A	X	NA	-	X
	B	NA	X	-	X

X = supported

- = not supported

NA = not applicable

4.4.4 Serial I/O

Debug information only provided in case of errors.

4.4.5 LED description

Table 21. LED description

LED name	STM32W108xB_TX	STM32W108xB_RX
D1	On when RF transmission is taking place	Not used
D3	Not used	On when an RF packet is received

4.4.6 Button description

Table 22. Button description

Button name	STM32W108xB_TX	STM32W108xB_RX
S1	Left click, Wakeup	Not used
S2, if available	Left click, Wakeup	Not used
S3, if available	Right click, Wakeup	Not used
S4, if available	Right click, Wakeup	Not used
S5, if available	Wakeup	Not used

4.4.7 Usage

The mouse demo is based on the detection of the MEMS axis accelerations that are translated to mouse movement and sent to the receiver attached to the PC. Flash one of the supported boards with the tx image and Flash another board with the rx image. Connect the mouse receiver to the PC and to use the mouse transmitter as a mouse for your PC. Tilt the mouse transmitter in a direction and the speed of the mouse is proportional to the tilt angle.

- Tilting towards the ground moves the mouse down
- Tilting towards the ceiling moves the mouse up
- Tilting left moves the mouse left
- Tilting right moves the mouse right

The mouse demonstration puts the device in deep sleep after 10 seconds of inactivity. To wake the mouse up, push any button.

4.5 SimpleMAC OTA bootloader demonstration application

The SimpleMAC OTA bootloader demonstration application is a simple program that demonstrates the Over the Air (OTA) ST bootloader protocol (see AN3262).

4.5.1 IAR project

Follow these steps to use the project with the IAR Embedded Workbench for ARM:

1. Open the IAR Embedded Workbench for ARM.
2. From the **File > Open > Workspace** menu, open the related IAR workspace.
3. Select the configuration you want to build.
4. Select **Project > Rebuild All**. This will recompile and link the entire application.
5. To launch a debug session, connect the IAR Jlink to the JTAG connector (P1) on the board.
6. Select **Project > Download and Debug**. The related binary image is downloaded into the STM32W108CC Flash memory, and the interactive debug session is started.
7. Connect the application board to a PC USB port. Open a hyperterminal on the corresponding USB virtual COMx port with the configuration as described in [Section 4.5.4: Serial I/O](#).

4.5.2 Jumper settings

Table 23. Jumper settings

Jumper name	STM32W108xB
JP1, if available	Irrelevant
P1, if available	5-6

4.5.3 Boards supported

Table 24. Boards supported

Board name	Board revision	STM32W108xB	STM32W108CC	ota_bootloader
Primer2 + MB850 A	A	X	NA	-
MB851	A,B,C	X	NA	X
	D	NA	X	X
MB954	A,B	X	NA	X
	C	NA	X	X
MB950A + MB953	MB953A	X	NA	X
	MB953B	NA	X	X
MB951	A	X	NA	X
	B	NA	X	X

X = supported

- = not supported

NA = not applicable

4.5.4 Serial I/O

The application listens for commands sent over the serial port with the following settings:

Table 25. Serial I/O

Parameter name	Value	Unit
Baud rate	115200	bit/sec
Data bits	8	bit
Parity	None	bit
Stop bits	1	bit

The list of supported commands is:

Table 26. Support commands

Command name	Command parameters	Description
loadImage	None	Find first node in bootloader mode and load test image to it
findBLNodes	None	Return the list of nodes in bootloader mode in the radio range
setDestEui64	eui64	Set the destination EUI64 for bootloader commands
getDestEui64	None	Return the currently used EUI64 for bootloader commands
get	None	GET command (see AN3262)
bget	None	GET command broadcast (see AN3262)
getid	None	GET_ID command (see AN3262)
bgetid	None	GET_ID command broadcast (see AN3262)
getversion	None	GET_VERSION command (see AN3262)
bgetversion	None	GET_VERSION command broadcast (see AN3262)
read	address bytes	READ command: read bytes of memory from address (see AN3262)
write	address bytes data	WRITE command: write bytes of data to memory address (see AN3262)
writeIncremental	bytes data	WRITE_INCREMENTAL command: write bytes of data to next memory address (see AN3262)
erase	pages page_list	ERASE command: erase a list of pages in Flash (see AN3262)
go	address	GO command: Jump to address (see AN3262)
help	None	List commands

- eui64 format: hexadecimal array (for example, {0080E10200000798})
- address format: decimal number or hexadecimal number (for example, 0xaabbccdd)
- bytes format: decimal number or hexadecimal number
- data format: hexadecimal array (for example, {aabbccddeeff0011})
- pages: decimal number or hexadecimal number
- page_list: hexadecimal array (for example, {11121314})

4.5.5 LED description

Table 27. LED description

LED name	STM32W108xB
D1	Not used
D3	Not used

4.5.6 Button description

Table 28. Button description

Button name	STM32W108xB
S1	Not used
S2, if available	Not used
S3, if available	Not used
S4, if available	Not used
S5, if available	Not used

4.5.7 Usage

The bootloader demonstration illustrates how to use the bootloader OTA commands described in AN3262. It also illustrates how to load a simple test image to a node in the OTA bootloader mode.

1. Load a first board with the IAP bootloader application.
2. Load the bootloader application on a second board.
3. Open a terminal on port COMyy and run the command loadImage.
4. Open a terminal on port COMxx and verify that the test application is now present.

Note: Notes and limitations

The user is requested to set the destination EUI64 address (setDestEui64 b eui64) before raising all other supported commands, except loadImage which will find the node by itself.

If the loadImage command fails, the user is requested to put the destination device in bootloader mode and to repeat the command (no recovery mechanism is currently supported).

Step 1 is only required when using boards with an STM32W108xB device.

The iap_bootloader application can also be built through the related IAR project.

4.6 SimpleMAC nodetest application

The SimpleMAC nodetest application is a low-level test program meant for the functional testing of RF modules (either your own custom-manufactured devices or those provided in the STM32W108 Kits), including token viewing, range testing, RSSI measurement, and special test modes of transmission as required for FCC and CE certification.

4.6.1 Building and downloading the SimpleMAC nodetest application

The SimpleMAC nodetest demonstration application runs on all application boards.

Use two application boards and program each of them with the nodetest binary image (simplemac-test.s37).

Note: The STM32-Primer2 and the MB850 board do not support the nodetest demonstration application.

Using the prebuilt simplemac-test.s37 binary image

To download and run the prebuilt nodetest binary image on the application board, use the stm32w_flasher utility with the prebuilt simplemac-test.s37 binary file. For information on how to use the stm32w_flasher utility, refer to the selected STM32W108xx kit user manual.

Using the IAR project

No IAR workspace is provided for the SimpleMAC nodetest application. The SimpleMAC nodetest is only delivered in binary format.

4.6.2 How to use the SimpleMAC nodetest application commands

For detailed information on how to use the SimpleMAC nodetest, refer to the user manual UM0978 “Using the SimpleMAC nodetest application”.

5 Designing an application using the SimpleMAC Library APIs

This section provides information and code examples on how to design and implement a SimpleMAC application.

The following functions are described:

- Initialization
- Configuring the radio
- Transmitting packets and managing transmit callbacks
- Enabling/disabling SFD event notifications
- Receiving packets and managing reception callbacks
- Configuring the coordinator filter mode
- Using AES security features
- Miscellaneous: energy detection, packet trace, CCA assessment.

5.1 Initialization

The following steps are required before starting to use the SimpleMAC library APIs:

1. Initialize the HAL layer.
2. Seed the random number generator.
3. Enable the interrupts.
4. Initialize the serial communication channel.
5. Perform one-time radio initialization and calibration (radio analog module, digital baseband and MAC) and leave the radio in the specified default mode (on or off).

The following pseudocode example illustrates the required initialization steps:

```
/* include library header file */
#include "include/phy-library.h"

void main(void)
{
    uint32_t seed;
    StStatus status;
    /* Initialization phase */
    .....
    /* seed random number generator */
    ST_RadioGetRandomNumbers((uint16_t *)&seed, 2);
    halCommonSeedRandom(seed);
    /* init serial */
    /* Initialize serial interface */
    .....

    /* Init radio in powered up mode */
```

```
    assert(ST_RadioInit(ST_RADIO_POWER_MODE_RX_ON) == ST_SUCCESS);
    while(1)
    {
        /* Simple MAC application specific steps */
    }
}
```

5.2 Configuring the radio

5.2.1 Radio sleep and wakeup

Call `ST_RadioSleep` and `ST_RadioWake` APIs to turn the radio off and on, respectively:

```
/* Turning off the radio */
ST_RadioSleep();

/* Turning on the radio */
ST_RadioWake();
```

5.2.2 Calibrating the radio

The radio needs to be recalibrated to ensure the same performance as environmental conditions change (temperature, etc.).

The following pseudocode example illustrates the required calibration steps:

```
void main(void)
{
    /* Initialization steps */
    ...
    ...
    while(1)
    {
        /* Periodically check if radio calibration conditions
           occur (due to temperature change)*/
        if (ST_RadioCheckRadio() == TRUE)
        {
            /* Perform necessary recalibration to counteract the
               effects of temperature changes since the last
               calibration */
            ST_RadioCalibrateCurrentChannel();
        }
    }
}
```


5.2.3 Setting radio channel, power level and power mode

Before starting transmitting or receiving a packet, select the radio channel and configure the transmit power and transmit power mode.

Pseudocode example for setting the radio channel

```
uint8_t channel = USER_CHANNEL;
/* Set radio channel */
ST_RadioSetChannel(channel);
```

Default radio channel is 11. The radio channel ranges between 11 and 26. The first time a channel is selected, all radio parameters are calibrated for this channel. This full calibration process can take up to 200 ms. Subsequent calls to *ST_RadioSetChannel()* with the same channel take less time (around 10 ms) because the values are retrieved from the Flash memory tokens.

Pseudocode example for setting the radio transmit power

```
int8_t power = USER_TX_POWER;
/* Set radio transmit power level */
ST_RadioSetPower(power);
```

Default transmit power level is 3 dBm. The radio power ranges from -43 to 8 dBm. The *ST_RadioSetPower()* function can set the power level to a value other than the one specified in the power parameter, since not all integer power levels are available as lower power levels. When a specific power level is not available, the next higher power level is used.

Pseudocode example for setting the radio power mode

```
uint16_t txPowerMode = USER_TX_POWER_MODE;
/* Set radio transmit power mode */
ST_RadioSetPowerMode(txPowerMode);
```

The *txPowerMode* parameter can take the following values:

bit 0

0: Normal mode.

1: Boost mode. Selecting the Boost mode increases the Rx sensitivity by approximately 1 dBm, and the Tx power by approximately 0.5 dBm.

bit 1

0: Enables bidirectional transmit path

1: Enables alternate transmit when using an external power amplifier.

5.3 Transmitting packets and managing transmit callbacks

5.3.1 Configuring the radioTransmitConfig variable

Before transmitting a packet, declare a variable, `radioTransmitConfig`, of *RadioTransmitConfig* type. The *RadioTransmitConfig* type corresponds to a structure containing the parameters and modes related to the packet transmission features (see [Table 29](#)). It must be initialized prior to calling the packet transmit API.

Table 29. *RadioTransmitConfig* members

Member	Description
boolean <code>waitForAck</code>	Wait for ACK if ACK request set in FCF.
boolean <code>checkCca</code>	Backoff and check CCA before transmitting the packet.
uint8_t <code>ccaAttemptMax</code>	Number of CCA attempts before failure. The value ranges from 0 to 5. The default value is 4.
uint8_t <code>backoffExponentMin</code>	Backoff exponent for the initial CCA attempt. The value ranges from 0 to 3. The default value is 3.
uint8_t <code>backoffExponentMax</code>	Backoff exponent for the final CCA attempt(s). The default value is 5.
uint8_t <code>minimumBackoff</code>	Minimum number of backoffs (suggested value is 0).
boolean <code>appendCrc</code>	Append CRC to transmitted packets.

If `radioTransmitConfig.checkCca` is TRUE, `ST_RadioTransmit()` performs CSMA-CA backoffs and CCA verifications before transmitting a packet. Otherwise, it starts the transmission process immediately. The STM32W108xx only supports CCA mode 1. CSMA-CA reports busy medium if the energy level expressed in dBm exceeds this threshold.

The related `radioTransmitConfig` variable can be modified only when no transmit operation is ongoing.

The pseudocode example below explains how to configure the related `radioTransmitConfig` variable:

```
RadioTransmitConfig radioTransmitConfig = {
    TRUE, // waitForAck;
    TRUE, // checkCca;
    4,    // ccaAttemptMax;
    3,    // backoffExponentMin;
    5,    // backoffExponentMax;
    0, //minimumBackoff
    TRUE  // appendCrc;
};
```

5.3.2 Setting and transmitting a packet

The following steps are required to transmit a packet:

1. The first field of the packet is the related length. If the `radioTransmitConfig.appendCrc` is TRUE the packet length byte must also take into account the two bytes of CRC. A packet with a two-byte payload is represented in memory as: {0x04, 0x00, 0x01, 0xc0, 0xc1} where 0xc0 and 0xc1 are the CRC bytes generated by hardware.

2. The packet has to be configured according to the MAC frame format described in [IEEE 802.15.4 general MAC frame format](#) :
 - a) Set the packet FCF, the packet source and the destination address mode. Refer to [Table 30](#) for an example of FCF configuration.

Table 30. Packet FCF configuration as 0x0821

Bits [0:2]	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bits [8:9]	Bits [10:11]	Bits [12:13]	Bits [14:15]
Frame type	Security enabled	Frame pending	Ack. request	Intra-PAN	Reserved		Destination addressing mode	Reserved	Source addressing mode
100	0	0	1	0	0	00	10	00	00
0x21						0x08			

- b) Specify the packet PAN identifier as well as its short or long addresses, according to the addressing mode selected on the packet FCF.

The pseudocode below shows an example of configuration and 13-byte packet transmission (plus 2 bytes for the CRC):

```
uint8_t txPacket[] = {
    0x0f, // packet length including two bytes for the CRC
    0x21, // FCF - data frame type, no security, no frame
           pending, ack request, no intra PAN
    0x08, // FCF - 16 bits short destination address, no
           source pan id and address
    0x00, // sequence number
    0x12, // destination pan id (lowest byte)
    0x23, // destination pan id (highest byte)
    0x02, // destination short address/node id (lowest byte)
    0x22, // destination short address/node id (highest byte)
    0x12, // packet data
    0x34, // packet data
    0x56, // packet data
    0x78, // packet data
    0x9A, // packet data
    0xBC, // packet data
};

St_Status status;

/* Sent the txPacket */
status = ST_RadioTransmit(txPacket);
```

If *radioTransmitConfig.checkCCA* equals TRUE, the CSMA-CA backoff(s) and CCA check(s) are performed using the default energy level (-75 dBm).

Below is a pseudocode example of energy threshold setting for the CCA assessment:

```
int8_t ed_cca_value = USER_ED_CCA_VALUE
/* Set the energy level used for CCA assessment */
ST_RadioSetEdCcaThreshold (ed_cca_value);
```

5.3.3 ISR callbacks for packet transmission

If the transmission process has successfully started, the *ST_RadioTransmitCompleteIsrCallback()* is called to indicate the completion status.

If the radio is busy transmitting, the *ST_RadioTransmit()* function returns an error and *ST_RadioTransmitCompleteIsrCallback()* will not be called.

Before sending a new packet, check the *ST_RadioTransmitIsrCompleteCallback()* status parameter to decide which action to perform. As an example, retransmit the packet if no acknowledgment has been received when the packet sent has the FCF ACK request bit set to 1.

The pseudocode below gives an example of transmit ISR callback:

```
void ST_RadioTransmitCompleteIsrCallback(St_Status status, uint32_t
sfdSentTime, boolean framePending)
{
    switch(status) {
        case ST_SUCCESS:
            break;
        case ST_PHY_TX_CCA_FAIL:
            /* Insert here user specific action */
            break;
        case ST_MAC_NO_ACK_RECEIVED:
            /* Insert here user specific action */
            break;
        case ST_PHY_ACK_RECEIVED:
            if (framePending) {
                /* Insert here user specific action */
            }
            else {
                /* Insert here user specific action */
            }
            break;
        default:
            /* Insert here user specific action */
            break;
    }
}
```

Note: The “framePending” parameter is *TRUE* if the received ACK indicates that a frame is pending. This is a very important information to notify the sender node that the destination node has pending data for it.

5.3.4 SFD event

It is possible to be notified of an SFD event (see [IEEE 802.15.4 general MAC frame format](#)) through the *ST_RadioSfdSentIsrCallback* (*uint32_t sfdSentTime*) callback.

The SFD event notification is disabled by default. To enable it, call the *ST_RadioEnableSfdSentNotification* function:

```
/* Enable SFD event notification */
ST_RadioEnableSfdSentNotification(TRUE);
```

Once enabled, an SFD event notification is sent through the related callback:

```
void ST_RadioSfdSentIsrCallback(uint32_t sfdSentTime)
{
    /* user code */
}
```

5.4 Receiving packets

5.4.1 Configuring radio filters for packet reception

To receive a packet, the radio device filters must have been configured. The following steps are required to configure radio filters:

1. Set the radio filtering mode according to the user application targets:

```
/* Set promiscuous mode: receive any packet on the selected radio channel */
/* Disable address filtering*/
ST_RadioEnableAddressFiltering(FALSE);
/* Turn off automatic acknowledgment */
ST_RadioEnableAutoAck(FALSE);
```

or

```
/* Receive packets only on a specific pan id and long or short address
(default configuration)*/
ST_RadioEnableAddressFiltering(TRUE);
```

2. Enable/disable the automatic transmission of an acknowledgment on packet reception (only for packets with FCF acknowledge request bit set to 1). Address filtering must be enabled for the automatic transmission of acknowledgment packet to occur:

```
/* Enable automatic packet acknowledgement (default is enabled) */
ST_RadioEnableAutoAck(TRUE);
```

3. Enable/disable the discarding of received packets for which a CRC verification has failed. When this feature is enabled, the library automatically removes the CRC bytes from the packets that passed the CRC verification:

```
/* Enable discarding packets which fail CRC (default is enabled) */
```

```
ST_RadioEnableReceiveCrc(TRUE);
```

4. When the address filtering mode is enabled, perform the following actions:

a) Set the radio PAN identifier:

```
uint16_t panid = USER_PAN_ID;
/* set the panid for filtering received packets */
ST_RadioSetPanId(panid);
```

b) Set the node identifier if the user application requires filtering on the 16-bit short address (or node identifier):

```
uint16_t nodeid = USER_NODE_ID;
/*set the nodeid (short address) for filtering received packets*/
ST_RadioSetNodeID(nodeid);
```

The *ST_RadioDataPendingforLongIdIsrCallback* and *ST_RadioDataPendingforShortIdIsrCallback* callbacks are called by the library when the packet source short or long address has been received. The library sets the frame pending bit in the outgoing acknowledgment only if the related callback returns TRUE. The user callback implementation must check if the receiving node has pending data for the detected sender source. This can be done by searching the source address in a lookup table containing the sender addresses for which there are data pending, and returning TRUE if there is pending data, and FALSE otherwise.

It is critical that these callback functions complete as quickly as possible, to ensure that the frame pending bit is set before the acknowledgment is sent back by the library. The sender node will be notified through the transmit callback that the frame pending bit has been received in the acknowledgment frame. The pseudocode below gives an example of the two callbacks:

```
boolean ST_RadioDataPendingShortIdIsrCallback(uint16_t shortId)
{
  /* Verify there are pending data for the sender node:
  look for the packet short address in a application table ...>
  */
  if <pending data>
    return TRUE;
  else
    return FALSE;
}

boolean ST_RadioDataPendingLongIdIsrCallback(uint8_t* longId)
{
  /* Verify there are pending data for the sender node:
  look for the packet long address in an application table ...>
  */

  if <pending data>
    return TRUE;
  else
    return FALSE;
}
```

5.4.2 ISR callbacks for packet reception

Each time a packet is received, the *ST_RadioReceiveIsrCallback(packet, ackFramePendingSet, time, errors, rssi)* callback is automatically called by the library.

The pseudocode below gives an example of a simple implementation of the *ST_RadioReceiveIsrCallback()* callback:

```
/* buffer where storing the received packet */
uint8_t rxPacket[128];

/* flag for checking that there's a packet being processed */
boolean packetReceived = FALSE;

void ST_RadioReceiveIsrCallback(uint8_t *packet,
                                boolean ackFramePendingSet,
                                uint32_t time,
                                uint16_t errors,
                                int8_t rssi)
{
    /* note this is executed from interrupt context */
    uint8_t i;

    /* Copy the packet to a buffer that can be accessed from the main loop.
    Don't do the copy if there is already a packet there being processed
    (packetReceived = TRUE) */
    if(packetReceived == FALSE) {
        for(i=0; i<=packet[0]; i++) {
            rxPacket[i] = packet[i];
        }
        packetReceived = TRUE;
    }
}
```

The `rxpacket[]` will be processed depending on the application target (see pseudocode below for an example):

```
void main(void)
{
    ...
    ...
    while(1) {
        /* print out any packets that were received */
        if(packetReceived == TRUE) {
            for(i=0; i<=rxPacket[0]; i++) {
                <print rxPacket[i]>;
            }
            /* The packet has been processed, so free the single entry
            queue up */
            packetReceived = FALSE;
        }
    }
}
```

5.5 Configuring the coordinator filter mode

The IEEE 802.15.4 standard supports the coordinator filter mode configuration. This feature allows receiving 802.15.4. data frames which have no destination address: the packets sent must have a destination addressing mode set to 00b (destination PAN identifier and destination short address not present). The source PAN identifier must match the coordinator PAN identifier, and the coordinator has to enable address filtering and set the same PAN identifier used for filtering the received packets.

Note: A node which is not a coordinator will not receive these packets.

Call the related APIs to enable the coordinator feature:

```
/* Enable coordinator feature (default is disabled)*/
ST_RadioSetCoordinator(TRUE).
```

Follow a pseudocode example showing a packet configured to be sent to a node with coordinator feature enabled and source pan id 0x2311:

```
uint8_t txPacket[] = {
    0x08, // packet length including two bytes for the CRC
    0x21, // FCF - data frame type, no security, no frame
           pending, ack request, no intra PAN
    0xc0, // FCF - no destination address mode (only source pan id)
    0x00, // sequence number
    0x11, // source pan id (lowest byte)
    0x23, // source pan id (highest byte)
    0x71 // packet data
};
```

The txpacket[] FCF field is configured as follows:

Table 31. FCF field of the packet sent to a coordinator node

Bits [0:2]	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bits [8:9]	Bits [10:11]	Bits [12:13]	Bits [14:15]
Frame type	Security enabled	Frame pending	Ack. request	Intra-PAN	Reserved		Destination addressing mode	Reserved	Source addressing mode
100	0	0	1	0	0	00	00	00	11 (or 10)
0x21						0xc0 (or 0x80)			

5.6 Radio AES security

Refer to the pseudocode below for an example of how to encrypt a block of data using an encryption key:

```
/* pointer to 128 bits of key data */
uint8_t key[128] = USER_KEY;
uint8_t block[128];

<Set the block of data>
...
/* Set the AES key */
ST_AesSetKey(key);

/* Encrypts the 128 'block' with the 'key' previously configured.
   The resulting encrypted data are stored at the same 'block'
   data.
*/
ST_AesEncrypt(block);
```

5.7 Radio MAC timer

The MAC timer is 20-bit long. Each LSB tick represents 1 μ s, and the MAC timer rolls over to zero approximately once every second. The MAC timer starts operating in free running mode when `ST_RadioInit()` is called. To retrieve the MAC timer value, call the `ST_RadioGetMacTimer()` API as shown below:

```
uint32_t mac_timer ;
/* Returns an instantaneous reading of the free-running MAC timer*/
mac_timer =ST_RadioGetMacTimer();
```

Note: *It is possible to enable/disable a MAC timer compare event (`ST_RadioEnableMacTimerCompare(enable)`) and to set the related reference compare value (`ST_RadioSetMacTimerCompare(compare_value)`). The `ST_RadioMacTimerCompareIsrCallback()` callback will be called by the library when a MAC timer comparison event occurs.*

5.8 Other radio features

5.8.1 Radio energy detection

To read the average energy level calculated over the previous eight symbol periods (128 μ s), call the `ST_RadioEnergyDetection()` API:

```
int8_t energy_level;

/* get the energy level on the selected radio channel */
energy_level = ST_RadioEnergyDetection();
```

Note: *`ST_RadioEnergyDetection()` returns the chip sensitivity limits (e.g. -97 dBm up to approximately -25 dBm).*

5.8.2 Radio CCA

To read the current status (clear or busy) of the selected channel, call the *ST_RadioChannelsClear* API:

```
boolean channel_status;  
  
/* Get the channel status (clear or busy) */  
channel_status = ST_RadioChannelIsClear();
```

5.8.3 Radio packet trace interface (PTI)

The STM32W108xx includes a packet trace interface (PTI) module which performs robust packet-based debugging. The PTI lines (PTI_EN, PTI_DATA on GPIO[4:5]) allow accessing all the received radio packets in a non-intrusive way.

To enable PTI, call the *ST_RadioEnablePacketTrace* API:

```
/* enable packet trace interface (default is enabled) */  
ST_RadioEnablePacketTrace(TRUE);
```

To read the current packet trace status (enabled or disabled), call the *ST_RadioPacketTraceEnabled* API, as shown below:

```
boolean packet_trace_status;  
packet_trace_status = ST_RadioPacketTraceEnabled();
```

5.8.4 Send a tone or a carrier wave

The SimpleMAC library provides some APIs which allow performing demodulated carrier wave (“tone”) transmission or modulated carrier wave transmission on the current channel. These APIs can be used to test scenarios such as transmit power level measurement.

To start/stop a demodulated carrier wave (“tone”) transmission, call the following APIs:

```
/* Start sending a tone */  
ST_RadioStartTransmitTone()  
  
/* Stop the tone transmission */  
ST_RadioStopTransmitTone(void);
```

To start/stop a modulated carrier wave transmission, call the following APIs:

```
/* Start sending a carrier wave */  
ST_RadioStartTransmitStream()  
/* Stop modulated carrier wave transmission */  
ST_RadioStopTransmitStream(void);
```

6 References

Table 32. List of references

Title	Content
IEEE 802.15.4 standard specification	IEEE 802.15.4 standard description
STM32W108 SimpleMAC library APIs documentation ⁽¹⁾	HTML document describing the SimpleMAC library APIs

1. This HTML file is provided within the SimpleMAC library.

7 List of acronyms

Table 33. List of acronyms

Term	Meaning
ACK	Acknowledgment
API	Application programming interfaces
CCA	Clear channel assessment
CSMA-CA	Carrier sense multiple access with collision avoidance
FCF	Frame control field
FCS	Frame check sequence
MAC	Medium access control
MFR	MAC footer
MHR	MAC header
PAN	Personal area network
PHY	Physical layer
PHR	PHY header
PSDU	PHY service data unit
RSSI	Received signal strength indication
SFD	Start-of-frame delimiter
SHR	Synchronization header

8 Revision history

Table 34. Document revision history

Date	Revision	Changes
12-Feb-2010	1	Initial release.
21-Apr-2010	2	<p>Updated API prefixes in Section 3.3: SimpleMAC library API naming conventions.</p> <p>Updated Section 4.1: SimpleMAC sample demonstration application. Modified sample image and removed Note 1 in Section 4.1.9. Section 4.1.9: changed Figure 9, Figure 10, Figure 11, and Figure 12; updated Table 12 and Running a planet application on the application board.</p> <p>Removed section 4.1.3 Limitations, as well as Limitations in Section 4.4.</p> <p>Updated function name and radio power range in Pseudocode example for setting the radio transmit power.</p> <p>Updated function name in Pseudocode example for setting the radio power mode.</p> <p>Updated structure and variable name in Section 5.3.1 and Section 5.3.2.</p> <p>Function names updated in Section 5.3.3, Section 5.3.4, Section 5.4.1, Section 5.4.2, Section 5.7, Section 5.8.3.</p> <p>Updated whole Section 5.8.4.</p>
30-Jul-2010	3	<p>Added Section 4.5: SimpleMAC OTA bootloader demonstration application and Section 4.6: SimpleMAC nodetest application.</p> <p>Reviewed initialization steps in Section 5.1: Initialization.</p>
25-Aug-2010	4	<p>Reviewed bootloader name as iap_bootloader.s37.</p> <p>Reviewed bootloader_demo running steps.</p>
14-Feb-2011	5	Added reference to STM32W108 application boards and removed reference to MB851 board.
16-Mar-2011	6	Added support for STM32W108xx kits.
12-May-2011	7	Added Section 4.4: SimpleMAC mouse demonstration application
16-Sep-2011	8	<p>Changes derived from SimpleMAC 1.1.0 release</p> <p>Added STM32W108C8, STM32W108CZ and STM32W108CC</p> <p>Updated Section 4.1: SimpleMAC sample demonstration application on page 16</p> <p>Updated Section 4.3: SimpleMAC talk demonstration application on page 29</p> <p>Updated Section 4.4: SimpleMAC mouse demonstration application on page 32</p> <p>Updated Section 4.5: SimpleMAC OTA bootloader demonstration application on page 34</p>

Date	Revision	Changes
22-Nov-2011	9	Minor text edits: STM32W108xx in Introduction The radio power ranges from -43 to 8 dBm on Pseudocode example for setting the radio transmit power on page 41 Add uint8_t minimumBackoff to Table 29: RadioTransmitConfig members on page 42
31-Aug-2012	10	Updated to adapt to SimpleMAC release 2.0.0: Updated Table 6 , Table 14 , Table 19 and Table 24 , Boards supported Added Section 4.2: SimpleMAC PC sun GUI application Edited pseudocodes in Section 5

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