UM0909
User manual

STM32W108xx ZigBee® RF4CE library

Introduction

This document describes the ST RF4CE library and how to use it to develop RF4CE compliant applications on an STM32W device. It describes the RF4CE protocol as defined by the ZigBee alliance and how the ST RF4CE library implements this protocol on STM32W devices. 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)

A description on how to perform common RF4CE operations as well as certain architecture-dependent operations is also included.

Finally, it describes reference applications for Target and Controller nodes as well as how to use an STM32W device with the ST RF4CE library alongside an external microcontroller (Coprocessor mode).

The ZigBee RF4CE library is designed to run on STM32W108 engineering samples and on the STM32W108xBU63 microcontroller.

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-SK STM32W-EXT STM32W-RFCKIT

Contents

List of tables

List of figures

1 RF4CE protocol description

1.1 Overview

The ZigBee® RF4CE standard was created by a consortium of companies with the objective to deliver a standardized specification for RF-controlled home entertainment products.

RF (radio frequency) remote controls are faster, more reliable and provide more freedom to operate devices from greater distances by removing the line-of-sight barrier found in today's IR (infrared) remote controls. They also enable advanced features such as two-way communication between the device and the remote control, creating a richer experience for consumers.

The RF4CE standard defines a network layer plus two application profiles for consumer electronics ZRC and ZID. The following sections provide more details on the network layer and the application profiles.

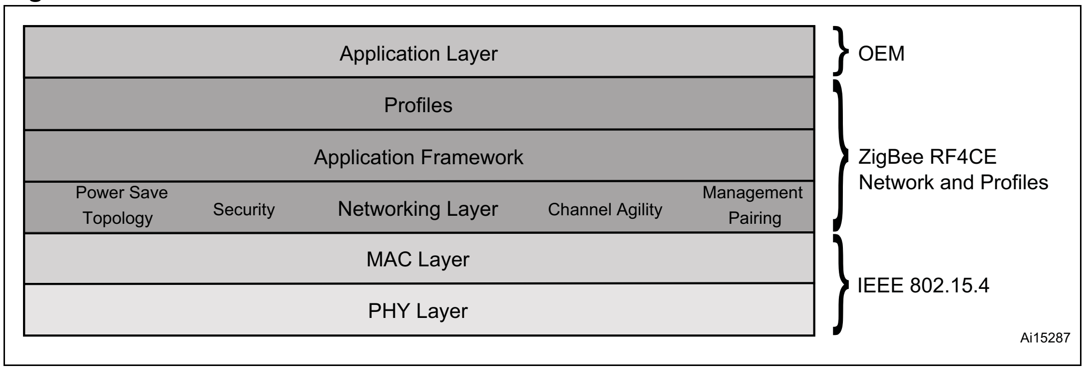
1.2 Network layer

The RF4CE network stack is a thin, flexible and future-proof layer with the following features:

- Based on 2.4 GHz MAC/PHY IEEE 802.15.4 standard
- Co-exists with other 2.4 GHz technologies
- Support for interoperability
- Support for secure communications
- Powersave mechanisms implemented in network layer
- Simple and intuitive pairing mechanism
- Allow for vendor-specific applications and transactions
- Support for many different applications

Figure 1 shows a layered representation of the RF4CE stack. For more details about the network layer, please refer to [1].

Figure 1. RF4CE stack overview



1.2.1 Node types

The RF4CE standard defines only two node types with different roles:

- Target Node with the following capabilities:
  - Network Startup
  - Full PAN capability
  - Accepts or declines a pairing request
  - Makes decision on operating channel (frequency agility)
- Controller Node with the following capabilities:
  - Initiates pairing and discovery process with Target nodes
  - Implements frequency agility
  - On-demand communication

1.2.2 Network topology

ZigBee RF4CE PANs are essentially point-to-point or star topologies with a single node acting as the target device and one or many nodes acting as remote controls. No routing is allowed and communication happens between nodes within RF range.

The ZigBee RF4CE network also supports multiple PANs and participation in multiple networks (*Figure 2*).

Figure 2. RF4CE multi-PAN network

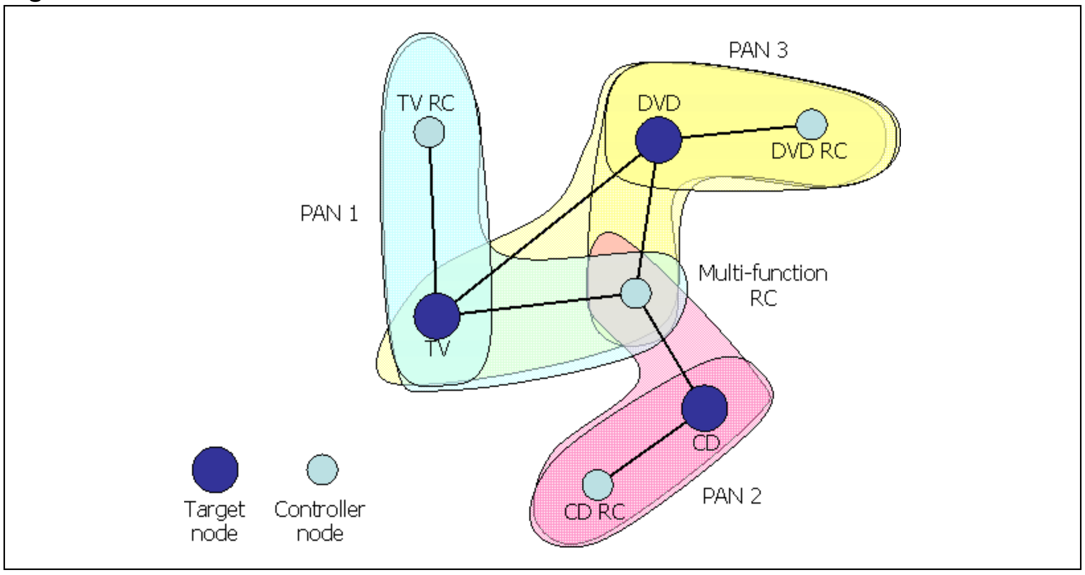


Figure 2 illustrates an example ZigBee RF4CE topology which includes three target nodes: a TV, a DVD and a CD player where each target node creates its own RC PAN. The TV, DVD and CD player also have dedicated remote controls which are paired to each appropriate target node. A multi-function remote control, capable of controlling all three target nodes itself, is added to the network by successively pairing to the desired target nodes. The DVD is also paired with the TV so that an external channel can be selected on the TV when a DVD is played.

As a consequence, this remote control network consists of three separate remote control PANs: one managed by the TV (PAN 1) containing the TV remote control, the multi-function remote control and the DVD; a second managed by the CD player (PAN 2) containing the CD remote control and the multi-function remote control and a third managed by the DVD (PAN3) containing the DVD remote control, multi-function remote control and the TV.

1.2.3 Frequency agility

ZigBee RF4CE networks operate on the following IEEE 802.15.4 channels:

- Channel 15: 2.425 GHz
- Channel 20: 2.450 GHz
- Channel 25: 2.475 GHz

Both target and controller node types support frequency agility.

Target nodes specify the PAN base frequency and can decide to switch frequencies on adverse channel conditions. The detection of a channel busy condition is implementation dependent.

Frequency reacquisition is achieved through a mechanism that allows other nodes by trying each frequency and once found, the new channel information is stored for future communications.

1.2.4 Discovery

The discovery procedure builds a list of devices in the “RF vicinity”.

Discovery requests are sent by the originating device (for example, a RC) and use a broadcast, multi-channel service so that multiple devices can respond.

The discovery request also contains originator information to allow the device to respond.

When a discovery request is received, recipient devices normally inform the application of the event. The application decides whether or not to respond to the discovery request.

The recipient device (for example, a television) sends a discovery response directly back to the originator (for example, a RC) using a unicast service.

The discovery response contains recipient information.

When the discovery procedure is completed, originator devices inform the application of all discovery information.

The application then decides whether to pair with a particular device.

1.2.5 Pairing

Pairing is a procedure required to establish a link between two devices in radio range that wish to communicate.

Pairing is required prior to device communications and it is performed only once. Pairing information is stored in non-volatile memory so that it can be retrieved after power cycling.

Pairing is similar to discovery where originator and recipient information is exchanged and the application has full control of whether to accept or not.

Both originator and recipient devices create pairing table entries that contain addressing information and security information, if applicable.

The application uses these entries via a reference index.

1.2.6 Message transmission and reception

Message exchanges are supported between paired devices only.

Transmission options include:

- Acknowledged
  - Originator data is confirmed by the recipient
- Unacknowledged
  - Originator data is not confirmed by the recipient
- Unicast
  - Originator data is sent to a specific recipient
- Broadcast
  - Originator data is sent to all recipients
- Single channel
  - Originator attempts transmission on the expected channel only
- Multiple channel
  - Originator attempts transmission using frequency re-acquisition mechanism
- All data can be sent secured or unsecured

The options can be combined depending on the application, for example:

- RCs typically use acknowledged, unicast and multiple channel options
- Target devices typically use unacknowledged, unicast and single channel options

1.2.7 Security

Security is established when pairing nodes that support security in their node capabilities.

The security mechanism has the following features:

- Utilizes AES-128 encryption
- Security mode: ENC-MIC-32
- Data confidentiality (via payload encryption)
- Data authentication (via Message Integrity Code)
- Replay protection (via frame counter)
- Nodes use 128-bit link keys
- Keys are generated automatically, if security is supported
- Keys are stored in the pairing table

The application can decide which transmissions require the use of security.

1.2.8 Power-saving

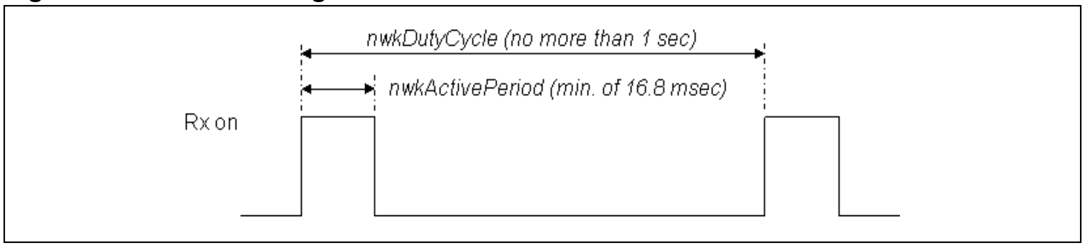
The RF4CE specification defines a 2-state power-saving scheme: Active and Standby.

In normal use cases, RCs simply power off when no buttons are being pressed, while target devices must also use power-saving techniques when in Standby.

Targets must also ensure a reasonable (human) reaction time to exit from Standby.

To achieve this, power-saving techniques use an active period during which the target wakes up, and a duty cycle after which the device repeats the active period as shown in *Figure 3*.

Figure 3. Power saving scheme


nwkDutyCycle (no more than 1 sec)
nwkActivePeriod (min. of 16.8 msec)
Rx on

1.3 ZRC application profile

The ZRC application profile is the first application profile defined for the RF4CE protocol. It aims at replacing remote controls that use traditional infrared technology.

It defines a very simple push-button pairing process between the remote control and the target device. The mechanism works in conjunction with existing ZigBee RF4CE discovery and pairing mechanisms. Discovery, pairing and security (optional) all take place at a single press of a button.

This application profile also defines a set of commands for basic CE device control, such as remote control pressed, remote control repeated and remote control released.

Refer to Document [3] for a description of these embedded HDMI CEC commands.

The ZRC also provides support for manufacturer-specific commands.

1.4 ZID application profile

The ZID application profile is the second application profile defined for the RF4CE protocol. It defines commands and procedures to enable devices such as mice, touchpads, keyboards, wands, Riva wheels or RC pointers.

The RF4CE ZID profile defines the over-air commands and mechanisms required to allow a Human interface device (HID) class device to communicate with a host. The profile defines two types of device: a HID class device and a HID adaptor. The HID class device can be used to support devices such as keyboards, mice or touchpads and the HID adaptor can be used to communicate through a HID class driver to some PC or other embedded host.

2 Using the STRF4CE API

2.1 Programming model

The STRF4CE library is a very efficient implementation based on a MAC/PHY layer specifically tailored for RF4CE applications. It features a simple and efficient NVM management system that stores non-volatile data and preserves the network layer state using power cycling methods.

An RF4CE API also implements power management functions only for the radio part in compliance with RF4CE specifications.

The same code base is used for both the target and controller node types.

The API is defined with a map close to the SAP defined in the specification.

The API is designed and implemented to be non-blocking; that is, the network layer operations will give back control to the application when waiting for an event.

The core of an RF4CE compliant application is implemented through a never-ending loop where the network layer state machine and application state machine are run.

```
while (1) {
   /* Non blocking call to run the application state machine */
   ApplicationTick();
   /* Non blocking call to run the network layer state machine */
   (void) NWK_Tick();
}
```

2.1.1 API to SAP mapping

The API provided by the STRF4CE library defines a set of functions that implement SAP mapping according to *Table 2*. In the table, the term 'F' means that the SAP is implemented as a function call, the term 'RF' means that the SAP is implemented as a function return value and the term 'C' means that the SAP is implemented as a function callback called in the context of `NWK_Tick` and is provided by the user.

Each API returns the following values:

- `SUCCESS`: Operation completed successfully
- `RF4CE_SAP_PENDING`: Operation started and pending; final result will be given by the matching callback.
- `RF4CE_BUSY`: Operation not started because the network layer is still performing some other operation or the network layer has not been initialized.
- Any other value: Error in the context of the specific operation.

Table 2. API to SAP mapping

SAP	Req	Conf	Ind	Rsp
AUTO-DISC	F	C		
COMM-STATUS			C	
DISCOVERY	F	C	C	F
GET/SET	F	RF		

Table 2. API to SAP mapping (continued)

SAP	Req	Conf	Ind	Rsp
PAIR	F	C	C	F
RESET	F	RF		
RX-ENABLE	F	RF		
START	F	C		
UNPAIR	F	C	C	F
UPDATE-KEY	F	RF		
DATA	F	C	C	

2.2 Initialization

The network layer is initialized by calling the `NWK_Init` API. The `NWK_Init` API is used to initialize the network layer according to the following parameters:

1. `nodeCap`: the node capabilities as defined by RF4CE specifications.
2. `forceColdStart`: If set to 'True', this boolean parameter allows the network layer to perform a cold start (for example, the first startup outside the factory). Otherwise it will perform a warm start, as defined by RF4CE specifications.

In normal use scenarios, the API should be called using the defined node capabilities and with `forceColdStart` set to `FALSE`.

If there is a mismatch between the content of the NVM memory and the node capabilities, the value `RF4CE_NVM_DATA_INVALID` is returned meaning that the NVM data contains invalid data; in this case, an initialization with a forced cold start is required. This is normally requested once when the device is first used outside the factory or in very special cases, but not, for example, in the event of power loss (such as a battery replacement).

2.2.1 Controller

The controller is initialized immediately and its status is returned accordingly. If the call is successful, the value 'SUCCESS' is returned and the network layer is ready for communication. An example code for controller initialization is:

```
status = NWK_Init(0, FALSE);
if (status == RF4CE_NVM_DATA_INVALID) {
   /* If warm start fails, try cold start */
   status = NWK_Init(0, TRUE);
}
```

2.2.2 Target

The Network layer is initialized immediately in case of a warm start returning `SUCCESS`. In case of a cold start, the API will return `RF4CE_SAP_PENDING`, meaning that network initialization will be completed with the call of the user-defined callback `NLME_START_confirm`. An example code for target initialization is:

```
void NLME_START_confirm (uint32_t *status)
{
    printf("RF4CE network started\r\n");
    networkStarted = TRUE;
}

status = NWK_Init(1, FALSE);
if (status == RF4CE_NVM_DATA_INVALID) {
   /* If warm start fails, try cold start */
   status = NWK_Init(1, TRUE);
   while (networkStarted == FALSE) {
   (void) NWK_Tick();
   }
}
```

2.3 Discovery

A device discovery operation is started either in a target or controller node with a call to the `NLME_DISCOVERY_request` API with the appropriate parameters. In case of success, the API returns the `RF4CE_SAP_PENDING` value and the discovery result is communicated through the user-defined callback `NLME_DISCOVERY_confirm`.

Only target nodes are notified of device discoveries by the user-defined callback `NLME_DISCOVERY_indication`. The target node can respond to a discovery indication using a `NLME_DISCOVERY_response` API. In case of success, this API returns the `RF4CE_SAP_PENDING` value and the discovery response status is communicated through the user-defined callback `COMM_STATUS_indication`.

An example code for device discovery is:

```
uint32_t status;
NLME_DISCOVERY_REQUEST_Type param;

param.DstPANId = 0xFFFF;
param.DstNwkAddr = 0xFFFF;
param.OrgAppCapabilities = 0x12;
param.OrgDevTypeList[0] = 0x01;
param.OrgProfileIdList[0] = 0x01;
param.SearchDevType = 0xFF;
param.DiscProfileIdListSize = 0x01;
param.DiscProfileIdList = {0x01, 00};
param.DiscDuration = 0x0016e36;
status = NLME_DISCOVERY_request (&param);
```

2.4 Pairing

Device pairing is required prior to starting any communication with an RF4CE node. Device pairing can be started either in a target or controller node with a call to the `NLME_PAIR_request` API with the appropriate parameters. In case of success, the API returns `RF4CE_SAP_PENDING` and a pairing operation result is communicated through the callback `NLME_PAIR_confirm`.

The target node can respond to a pair indication using an `NLME_PAIR_response` API. In case of success, this API returns the value `RF4CE_SAP_PENDING` and the pair response status is communicated through the user-defined callback `COMM_STATUS_indication`.

An example code for device pairing is:

```
uint32_t status;
NLME_PAIR_REQUEST_Type param;
IEEEAddr dstLongAddr = {0x00, 0x11, 0x22, 0x33, 0x44, 0x55, 0x66, 0x77};

param.LogicalChannel = 15;
param.DstPANId = 0x1234;
memcpy(param.DstIEEEAddr, dstLongAddr, sizeof(IEEEAddr));
param.OrgAppCapabilities = 0x13;
param.OrgDevTypeList[0] = 0x01;
param.OrgProfileIdList[0] =  0x01;
param.KeyExTransferCount = 3;
status = NLME_PAIR_request(&param);
```

2.5 Message exchanges

Messages are transmitted through the use of the `NLDE_DATA_request` and can be sent by both a controller node and a target node. The RF4CE standard states that the following types of communication are possible:

- Controller to target
- Target to controller
- Target to target

Messages can be exchanged only between nodes that have previously been paired; that is, a valid pairing entry exists in the pairing table.

In case of success, the API returns `RF4CE_SAP_PENDING` and the message transmission result is communicated through the call of `NLDE_DATA_confirm`. Any other value returned by the API should be considered as an error condition.

Message reception is indicated to the user application through the user-defined callback `NLDE_DATA_indication`.

An example message exchange is:

```
uint32_t status;
NLDE_DATA_REQUEST_Type param;

param.nsduLength = 1;
param.nsdu[0] = 0x11;
param.PairingRef = 0;
param.ProfileId = 0x01; //Consumer Electronics Remote control
param.VendorId = 0xfff1; //Test vendor id #1
param.TxOptions = 0x4c; // Unicast - nwk address - ack - security -
```

```
                                // multiple channel - no channel designator
                                // - vendor specific
status = NLDE_DATA_request(&param);
```

2.6 Security

The security is automatically activated by the stack when the node capabilities of paired nodes show that the node supports security (see `nodeCap` parameters in *Section 2.2*).

Even if the security is enabled over a couple of paired nodes, the application has still the ability to select between secure and non-secure communications when using the `NLDE_DATA_request` API. If the security is not enabled, only non-secure communications are allowed.

2.7 Timer

A simple timer API is used by the stack to handle timeouts and delays. The timer has a resolution of 1 µs.

An application can use both API `TIME_CurrentTime` and `TIME_ELAPSED` timers.

2.8 Power consumption

The stack contains a built-in mechanism to support power-saving schemes.

2.8.1 RF power-down

The power-down of the RF part is achieved through a call to `NLME_RX_ENABLE_request` with `RxOnDuration` parameters set to 0.

The stack confirms the power-down of the RF part when the `NWK_Tick` API return value has the bit `RF4CE_STATE_POWER_DOWN` set.

An example code for RF power-down is:

```
NLME_RX_ENABLE_request(0);
while ((NWK_Tick() & RF4CE_STATE_POWER_DOWN) == 0);
```

A helper function `NWK_PowerDown()` is provided to implement the above code and its use is recommended.

The stack can be brought back to normal operation with a call to `NLME_RX_ENABLE_request` with `RxOnDuration` parameters set to `0xFFFFFF` or using the helper function `NWK_PowerUp(FALSE).`

2.8.2 SOC power down

For a maximum battery life in real-life applications, it could be useful to shut down the entire SOC. In this case, the sequence of operations should be as follows:

```
NWK_PowerDown();
 ATOMIC(
   /* Configure RX, TX pins to achieve minimum power consumption on MB851 */
```

```
    GPIOB->ODR &= ~((1 << 1) | (1 << 2));
    halGpioConfig(PORTB_PIN(1), GPIO_Mode_IN_PUD);
    halGpioConfig(PORTB_PIN(2), GPIO_Mode_IN_PUD);
    halPowerDown();
    halSleepWithOptions(SLEEPMODE_NOTIMER,
BUTTON_S1_WAKE_SOURCE|UART_RX_WAKE_SOURCE | 0x20); //DeepSleep 2; 0x20 is
to keep happy Primer 2
    halPowerUp();
    );
  NWK_PowerUp(TRUE);
  uartInit();
```

2.8.3 RF standby

RF4CE specifications define a mechanism used to reduce the power consumption using the `NLME_RX_ENABLE_request` function with parameter `RxOnDuration` set to `nwkActivePeriod`. A simple piece of code to activate standby is shown below:

```
{
   uint32_t activePeriod;
   NLME_Get (nwkActivePeriod_ID, 0, &activePeriod);
   NLME_RX_ENABLE_request(activePeriod);
}
```

2.9 Non volatile memory management

The ST RF4CE stack contains a module used to manage NVM storage using 1 Kbyte of Flash memory. NVM usage is transparent to the user, but some interaction with the application is required to limit Flash wearing.

Flash wearing is limited using a cache of the NVM data in RAM. This cache needs to be flushed into the actual flash periodically, so that it is not lost in case of a power failure. The following code provides an example of how to flush the NVM cache:

```
  retVal = NWK_Tick();
  /* Check whether cache flush is required */
  if (retVal & RF4CE_STATE_NEED_CACHE_FLUSH) {
NWK_Flush();
  }
```

The `NWK_Tick` return value gives an indication when cache and NVM are not consistent.

A call to `NWK_Flush()` is not mandatory and can be delayed if necessary since the `NWK_Flush` operation requires about 40 ms to complete. The application can choose when it is more appropriate to call it and how often.

2.10 RF4CE stack configuration

The ST RF4CE library allows the configuration of certain stack parameters at run time. These stack parameters (*Table 3*) are, according to the specification, constants but implementation-dependent.

Table 3. Configurable stack parameters

Name	Valid range	Default value	Description
`nwkcMaxNodeDescListSize`	Not specified	3	Not changeable without recompiling the stack.
`nwkcMaxPairingTableEntries`	Not specified	5	Not changeable without recompiling the stack.
`nwkcNodeCapabilities`	Not specified	N/A	Do not change this, but use `NWK_Init` to set the node capabilities.
`nwkcVendorIdentifier`	16 bit value	0xFFF1	Vendor ID, please use `NWK_Config` to change it.
`nwkcVendorString`	7-character string	"ST"	Vendor string, please use `NWK_Config` to change it.

For a complete description of the parameters, please refer to documents [1], [2] and [6].

The stack configuration is required prior to cold starting the stack using `NWK_Init`; it is stored in the non volatile memory.

The following code shows how to configure the stack using `NWK_Config`:

```
void NLME_START_confirm (uint32_t *status)
{
  printf("RF4CE network started\r\n");
  networkStarted = TRUE;
}

status = NWK_Init(0, FALSE);
if (status == RF4CE_NVM_DATA_INVALID) {
   /* If warm start fails, try cold start */
   uint16_t myVendorId = 0xabcd;
   NWK_Config(nwkcVendorIdentifier_ID, &myVendorId);
   NWK_Config(nwkcVendorString_ID, "Vendor");
   status = NWK_Init(1, TRUE);
   while (networkStarted == FALSE) {
   (void) NWK_Tick();
   }
}
```

All other network parameters can be modified using the `NLME_Set` API.

Below is an example of how to set up the `nwkUserString` parameter. This should be done only once after a cold start.

```
NLME_SET_Type val;
```

```
val.NIBAttribute = nwkUserString_ID;
val.NIBAttributeIndex = 0;
val.NIBAttributeValue = "STM32W Target";
```

3 Designing an application using the RF4CE library

The code below shows a skeleton application for implementing an RF4CE target device.

```
#include "rf4ce.h"
void NLDE_DATA_confirm(NLDE_DATA_CONFIRM_Type *param)
{
  < Your code here >;
}
void NLME_START_confirm(uint32_t *status)
{
  printf("RF4CE network started\r\n");
  networkStarted = TRUE;
}
void NLME_AUTO_DISCOVERY_confirm(NLME_AUTO_DISCOVERY_CONFIRM_Type
 *param)
{
  < Your code here >;
}
void NLME_DISCOVERY_confirm (NLME_DISCOVERY_CONFIRM_Type *param)
{
  < Your code here >;
}
void NLME_PAIR_confirm(NLME_PAIR_CONFIRM_Type *params)
{
  < Your code here >;
}
void NLME_UNPAIR_confirm(NLME_UNPAIR_CONFIRM_Type *param)
{
  < Your code here >;
}
void NLDE_DATA_indication(NLDE_DATA_INDICATION_Type *param);
{
  < Your code here >;
}
void NLME_DISCOVERY_indication(NLME_DISCOVERY_INDICATION_Type *param)
{
  < Your code here >;
}
void NLME_PAIR_indication (NLME_PAIR_INDICATION_Type *params)
{
  < Your code here >;
}
void NLME_COMM_STATUS_indication (NLME_COMM_STATUS_INDICATION_Type *params)
{
  < Your code here >;
}
void NLME_UNPAIR_indication (uint8_t *PairingRef)
{
  < Your code here >;
}
int main (void)
{
  /* Initialization phase */
  ........

  /* init serial */
/* Initialize serial interface */
................

status = NWK_Init(1, FALSE);
  if (status == RF4CE_NVM_DATA_INVALID) {
     /* If warm start fails, try cold start */
     uint16_t myVendorId = 0xabcd;
     NWK_Config(nwkcVendorIdentifier_ID, &myVendorId);
     NWK_Config(nwkcVendorString_ID, "Vendor");
     status = NWK_Init(1, TRUE);
     while (networkStarted == FALSE) {
   (void) NWK_Tick();
     }
  }

  while (1) {
   /* Non blocking call to advance application state machine */
   ApplicationTick();
   /* Non blocking call to advance network layer state machine */
   (void) NWK_Tick();
  }
}
```

4 ZRC demo application

The ZigBee RF4CE demo applications target the ZigBee RF4CE ZRC (Consumer electronic remote control) profile for remote control and target devices for the scenarios listed in *Table 4*.

Table 4. ZigBee RF4CE ZRC demo applications scenarios

RF4CE remote control	RF4CE target device
RS232 RC	RS232 Target
ST Virtual RC	ST Virtual TV
ST Virtual RC	Sony infrared TV

All combinations between RCs and targets are supported.

These scenarios demonstrate simple RF4CE interactions between an RC and a target device with:

- Discovery and pairing
- Secure communications
- Data transmission
- Power management

The STM32W108 RF4CE ZRC firmware is the same in both RC and target devices and can be used in different scenarios according to *Section 4.4: RS-232 remote control and target applications*, *Section 4.5: ST Virtual RC and TV* and *Section 4.6: ST Virtual RC and Sony Infrared TV (with an RF4CE I/R extender)*.

This firmware can also be considered as a reference application for customers who want to implement a ZRC profile on top of the ZigBee RF4CE stack.

4.1 Firmware common features

The RF4CE ZRC firmware provides a user interface, through an RS-232 interface, with LEDs and push-buttons. When loaded on any board, the firmware user interactions are those described in *Table 5*.

Table 5. Firmware user interface

User interface item	Direction	Description
RS-232 via USB	Input/Output	Command line interface (see *Section 4.4*)
LED D3 (Yellow)	Output	Heartbeat LED should be flashing at all times, except when in Standby.

Table 5. Firmware user interface (continued)

User interface item	Direction	Description
LED D1 (Green)	Output	ON: RF4CE network initialized as target.
		OFF: RF4CE network layer not initialized or initialized as remote control.
		Blinks every sec: RF4CE network layer cold start in progress.
		Blinks every 0.2 sec: RF4CE target node waiting for pairing from remote control.
Push-button S1	Input	LED D1 OFF: Press to start the node as a target.
		LED D1 ON: Press to enable pairing.
		LED D1 ON: Press for more than 2 seconds to bring the RF4CE node to unconfigured state.

The following subsection provides a description of the building and running steps of the demonstration applications using the IAR projects delivered within the RF4CE software library package as a reference. The available workspaces provide reference examples for the STM32W108CC boards.

4.2 Building the firmware

The firmware can be built from the IAR Embedded Workbench sources using the related IAR project file.

4.3 Programming the firmware

The firmware can be programmed in the boards using the IAR Embedded Workbench or using the *stm32w_flasher* utility.

For information on how to use the *stm32w_flasher* utility, refer to the *STM32W-SK and STM32W-EXT starter and extension kits for STM32W108xx user manual* (reference: UM0894).

4.4 RS-232 remote control and target applications

In this demo scenario, the user interacts with the boards using a PC HyperTerminal and the user can set a node as an RF4CE target or as an RF4CE controller (*Figure 4*).

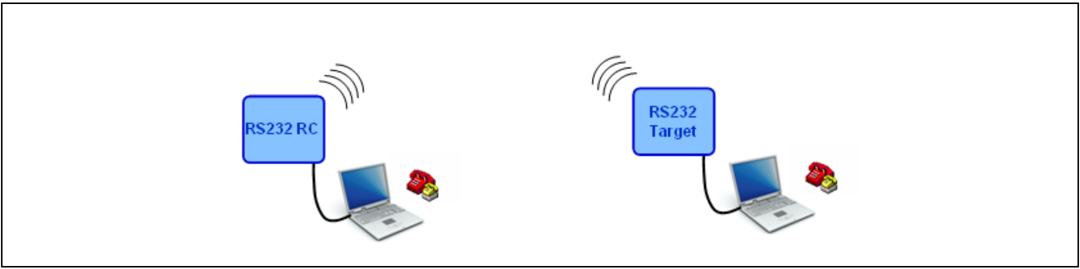
This demo scenario uses two boards and it can be run even on a single PC.

The RS-232 port in the PC should be set according to the values shown in *Table 6*.

Table 6. RS-232 settings

Parameter	Setting
Baud rate	115200
Data bits	8
Parity	None
Stop bits	1
Flow control	Xon/Xoff

Figure 4. RS-232 RC and target node



The demo supports the commands (case-sensitive) as shown in *Table 7* over the HyperTerminal. (The two devices are named **#1** and **#2** in reference to the STM32W108 boards and are both loaded with the *rf4ce* firmware image.)

Table 7. Firmware commands

Command	Description
`T`	Configure the node as the target
`C`	Configure the node as the controller
`D`	Discovery & pair procedure
`Z`	Discovery & pair procedure from a target
`p`	Dump pairing table
`R`	Device software reset
`e`	Clear pairing table
`E`	Erase the NVM storage
`S`	Enable the power save
`A`	Disable the power save
`O`	Update the remote control firmware over the air from the target. (The firmware sent is the target Flash image). Note: the remote control and the target should contain the bootloader code (*iap_bootloader.s37*) at the bottom of the Flash memory space.
`?`	Print Help menu
`+`	Send command key (pressed): volume up
`-`	Send command key (pressed): volume down
`>`	Send command key (pressed): channel up
`<`	Send command key (pressed): channel down

Table 7. **Firmware commands (continued)**

Command	Description
`0-9`	Send command key (pressed): channel 0-9
`ESC`	Enter the string command mode

To run the demo applications, type the following command sequences:

1. **#1, #2**: If the devices are not configured, the prompt is: “`Unconfig>`”. Otherwise type `E` to cancel any previous configuration.
2. **#1**: Type command `T` to configure the target. Wait approximately 5 seconds to end the RF4CE network initialization. If the initialization is correct, the prompt will be: `Target(-1)>` (`-1` indicates that the device is not paired).
3. **#2**: Type command `C` to configure the controller (remote control). If the initialization is correct, the prompt is: `Controller(-1)>` (`-1` indicates that the device is not paired).
4. **#1, #2**: Type command `D` and wait for the confirm messages on both boards.

Below is an example of a log of discovery and pair messages with status OK:

CONTROLLER:

```
Controller(-1)>D
<CERC_DSC_PAIR>
Status = 00000100
<CERC_DSC_PAIR_END>
Controller(-1)><CERC_PAIR_CONFIRM>
Status = 00000000
PairingRef = 00
VendorId = FFF2
VendorString = Vendor
AppCapabilities = 13
UserString = STM32W Target
DevTypeList = 02
<CERC_PAIR_CONFIRM_END>

Controller(0)>
```

TARGET:

```
Target(-1)>D
<CERC_DSC_PAIR>
Status = 00000100
<CERC_DSC_PAIR_END>
Target(-1)><CERC_PAIR_INDICATION>
Status = 00000000
PairingRef = 00
VendorId = FFF1
VendorString = ST
AppCapabilities = 13
UserString = STM32W RC
DevTypeList = 01
```

```
PANId = FFFF
Address = 0080E1020000026C
<CERC_PAIR_INDICATION_END>
<CERC_RF4CE_COMM_STATUS_INDICATION>
Status = 00000000
PairingRef = 00
PANId = FFFF
Address = 0080E1020000026C
<CERC_RF4CE_COMM_STATUS_INDICATION_END>

Target(0)>
```

Furthermore, you can verify that the pairing operation is successful by checking the pairing table contents.

#1, #2: Type the command `p` to verify that the devices are paired.

You can find below an example of the device paired. The status must be 0x02; otherwise, the discovery and pair procedure has failed for some reason.

```
Controller(0)>p
<CERC_PAIRING_TABLE>
c status sNWK CH dstIEEEAddr      dPAN dNWK frmcnt   cp linkKey
0 02     A645 19 0080E10200000261 72FA E596 00000409 07
76ECD8D2C68C71800069D9B91B3667A7
1 FF     FFFF FF FFFFFFFFFFFFFFFF FFFF FFFF FFFFFFFF FF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
2 FF     FFFF FF FFFFFFFFFFFFFFFF FFFF FFFF FFFFFFFF FF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
3 FF     FFFF FF FFFFFFFFFFFFFFFF FFFF FFFF FFFFFFFF FF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
4 FF     FFFF FF FFFFFFFFFFFFFFFF FFFF FFFF FFFFFFFF FF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
```

You can now press keys on the controller and check that they are correctly received by the target.

1. **#2** (remote control). Type commands:
   – Change channel keys 0-9
   – Volume up +
   – Volume down -
   – Channel up >
   – Channel down <
2. **#1** (target). For each key pressed and released, it receives two packets:
   a) One with payload `0x01` (`KEY_PRESSED`) and containing an hex number `0x##` according to the following list:
      `KEY_PRESSED` plus
      `0x20` = “Channel 0” -0x29 = “Channel 9”
      `0x41` = “VolUp”
      `0x42` = “VolDown”

`0x30` = “ChannelUp”
`0x31` = “ChannelDown”

b) One with payload `0x03` (`KEY_RELEASED`).

If you keep the key pressed, the ZRC profile sends a packet with payload 0x02 to indicate that the key is being repeated.

Note: For each key received, the infrared LED in the target emits a Sony RC compatible sequence. This is useful for driving a Sony TV with an infrared remote control.

4.5 ST Virtual RC and TV

This demo scenario uses two boards and two PC applets to emulate an RF4CE remote control and an RF4CE TV (see *Figure 5*).

The ST Virtual RC is a PC applet implementing a remote control driven through a PC GUI.

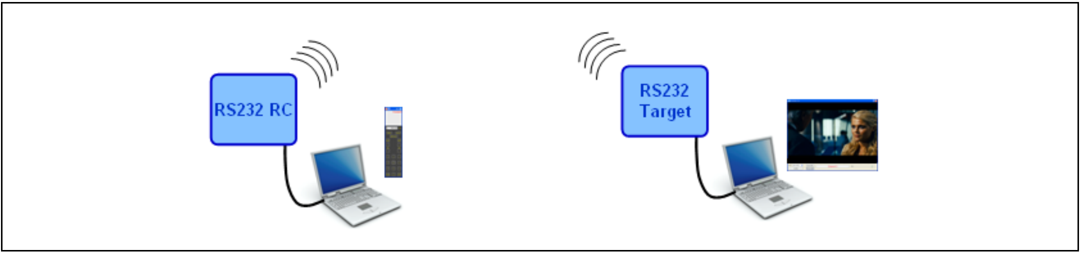
The ST Virtual TV is a PC applet implementing a TV driven through a PC GUI.

To start the demo, please make sure you have two boards connected to the PC through the USB port and perform the following steps:

1. Run the ST Virtual RC and ST Virtual TV applications from the PCApplet folder.
2. On the Virtual RC application, select a serial port from the drop-down menu. (If the firmware is not present in the board, it will be automatically downloaded by the application.) Wait for the initialization procedure to complete (“ST RF4CE RC Ready” message is displayed).
3. On the Virtual TV application, select a serial port from the drop-down menu. (If the firmware is not present in the board, it will be automatically downloaded by the application.) Wait for the initialization procedure to complete (“ST RF4CE TV Ready” message is displayed).
4. On the Virtual RC application, select 🔍 to start the pairing procedure.
5. On the Virtual TV application, select 🔍 to start the pairing procedure.
6. If everything is OK, the message “Paired” is displayed on the TV and a confirmation message with technical details is displayed on the RC after a few seconds.
7. The demo is now operational and the key presses on the virtual RC will perform the requested action on the virtual TV as specified in *Table 8*.

Note: If you run again the demo with the same boards as RC and TV, the devices are already paired and steps 4, 5 and 6 are not necessary.

Figure 5. RF4CE Virtual RC and TV



4.5.1 ST Virtual RC

The ST Virtual RC is a PC GUI application that emulates an RF4CE RC and supports the commands listed in *Table 8*.

Table 8. Button functions in ST Virtual RC

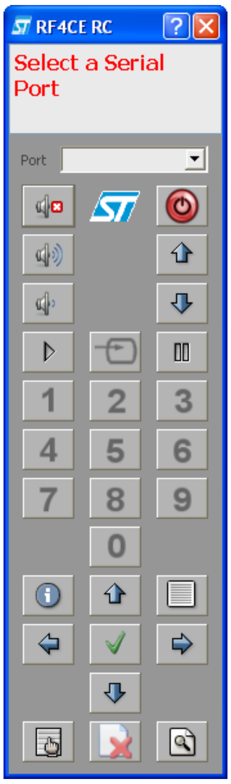
Key label	ZRC code	Infrared code	Description
🔇	0x43	0x14	Mute button
🔊	0x41	0x12	Volume up button
🔉	0x42	0x13	Volume down button
⏻	0x40	0x15	Standby button
⇧	0x30	0x10	Channel up button
⇩	0x31	0x11	Channel down button
▷	0x44	0x1A	Play button
⏸	0x46	0x19	Pause button
⎆	0x69	0x25	AV button
°°	0x20-0x29	0x09, 0x01-0x08	Digit button
ⓘ	0x35	0x3A	Info button
⇧	0x09	0x60	Menu button
⇩	0x01	0x74	Up button
☰	0x02	0x75	Down button
⇨	0x04	0x33	Right button
⇦	0x03	0x34	Left button
✓	0x00	0x65	Select/OK button
✗	N/A	N/A	Cancel all paired devices

Table 8. Button functions in ST Virtual RC (continued)

Key label	ZRC code	Infrared code	Description
👆	N/A	N/A	Show the list of paired devices
🔍	N/A	N/A	Search and pair RF4CE target

Figure 6 shows a snapshot of the ST Virtual RC application.

Figure 6. ST Virtual RC


RF4CE RC

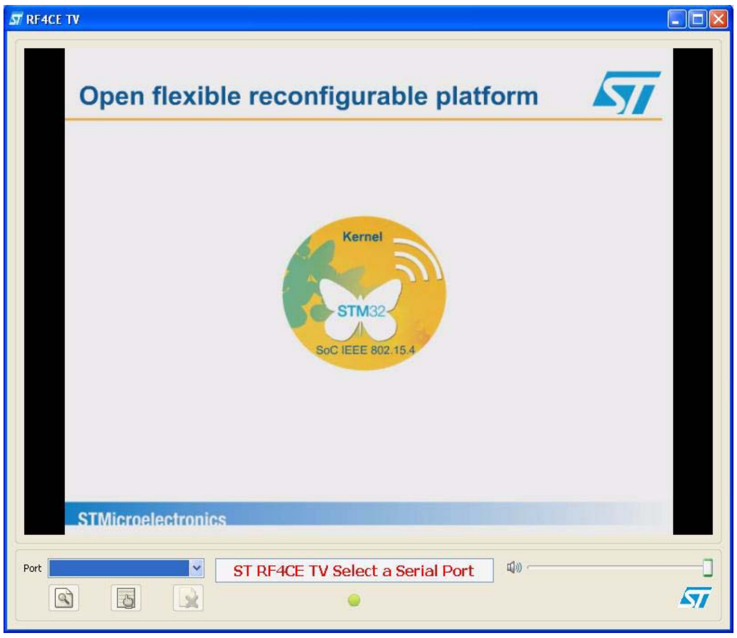
Select a Serial Port

4.5.2 ST Virtual TV

The ST Virtual TV is a PC GUI application that emulates an RF4CE TV and supports the following features:

- 12 channels, playing video from files
- Volume control
- Mute
- Channel change
- Play/Pause
- Pair button
- Erase pairing table button
- Paired devices information

Figure 7. ST Virtual TV screenshot


RF4CE TV
Open flexible reconfigurable platform
Kernel
STM32
SoC IEEE 802.15.4
STMicroelectronics
Port
ST RF4CE TV Select a Serial Port

4.6 ST Virtual RC and Sony Infrared TV (with an RF4CE I/R extender)

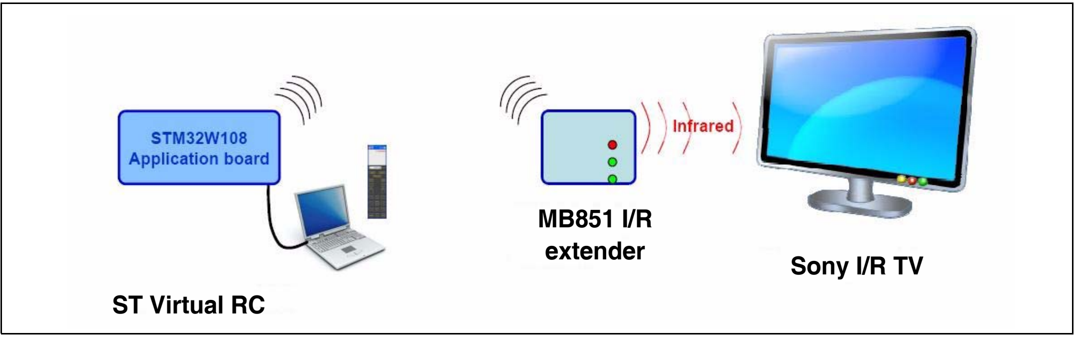
This demo scenario targets a demo and an infrared TV supporting Sony codes (see *Figure 8*).

The RF4CE I/R extender is an STM32W108 MB851/MB954 board which acts as an RF4CE-Infrared bridge between the ST Virtual RF4CE RC and a Sony TV. Please note that:

- *rf4ce* firmware is requested to be loaded in the STM32W108 MB851/MB954 board
- Jumper JP1 should be fitted

The Sony infrared TV is a normal TV supporting Sony I/R codes as listed in *Table 8* with the MB851/MB954 board placed close to the infrared receiver.

Figure 8. ST Virtual RC and Sony infrared TV



The ST RF4CE I/R extender supports the following features:

- Network layer cold start by pressing button S1 when LED D1 is off.
- Pairing mode when LED D1 is on by pressing button S1.
- Erase pairing table and bring to the unconfigured state when pressing button S1 for more than 2 seconds.

Note: This demo can also run using the STM32-Primer2 with MB850 available only with the STM32W108B-SK kit (boards with STM32W108CB devices).

5 ZID demonstration application

This is a mouse demonstration application, based on the RF4CE ZID application profile.

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5.1 IAR project

There is a single firmware image to perform the roles of mouse and dongle. The mouse is the device acting as MEMS based mouse device which sends ZID RF4CE messages to the dongle. The dongle is one of the supported ST boards connected to PC via USB and acting as an RF4CE ZID Host adapter. The firmware is not configured initially and users can configure it using button press combinations (see *Table 12: Button description*).

5.2 Jumper settings

Table 9. Jumper settings

Jumper name	Role	STM32W108
JP1, if available	MOUSE	Fitted
	DONGLE	Does not matter
	MOUSE, DONGLE	1-2 (battery) 5-6 (USB)

5.3 Boards supported

Table 10. Boards supported

Board name	Board revision	Role	STM32W108xB	STM32W108CC
MB851	A,B	MOUSE	X	NA
	A,B	DONGLE	-	NA
	C	MOUSE, DONGLE	X	NA
	D	MOUSE, DONGLE	NA	X
MB954	A	MOUSE	X	NA
	A	DONGLE	-	NA
	B	MOUSE, DONGLE	X	NA
	C	MOUSE, DONGLE	NA	X
MB950A + MB953	MB953A	MOUSE, DONGLE	X	NA
	MB953B	MOUSE, DONGLE	NA	X
MB951	A	MOUSE	-	NA
	A	DONGLE	X	NA
	B	MOUSE	NA	-
	B	DONGLE	NA	X

X = supported

- = not supported

NA = not applicable

5.4 Serial I/O

Debug info only in case of errors.

5.5 LED description

Table 11. LED description

LED	Role	STM32W108
D1	NONE	OFF Blinks twice if configured as a mouse.
	MOUSE	ON only when an RF transmission is taking place. Blinks every 0.1 second while pairing. Blinks twice if the configuration is deleted.
	DONGLE	ON during normal operation. Blinks every 0.5 seconds while network startup. Blinks every 0.1 second while pairing.
D3	MOUSE, DONGLE	Flashing. OFF when in deep sleep.

5.6 Buttons description

Table 12. Button description

Button	Role	Paired	STM32W108
S1	NONE	N/A	If held down while resetting for less than 5 seconds, configured as a mouse. If pressed after reset, configured as dongle.
	MOUSE	No	If held down while resetting for more than 5 seconds, delete configuration as mouse. If pressed, start pairing.
	MOUSE	Yes	If held down while resetting for more than 5 seconds, delete configuration as mouse. If pressed left click, wakeup.
	DONGLE	Does not matter	If pressed for more than 2 seconds, reset pairing table. If pressed shortly, start pairing.
S2, if available	MOUSE	Yes	Left click, wakeup
S3, if available	MOUSE	Yes	Right click, wakeup
S4, if available	MOUSE	Yes	Right click, wakeup
S5, if available	MOUSE	Yes	Wakeup

5.7 Usage

The RF4CE ZID demo is based on the application profile version 0.9 (08 March 2011). It demonstrates the basic steps to configure two boards, one as a HID device and the other as a HID USB adaptor. The HID device is a mouse, which is based on the detection of the MEMS axis accelerations that translate to mouse movements and are sent to the receiver attached to the PC. Please flash the supported boards with hid_rf4ce image. To start up the demo, follow the steps below:

1. Connect the HID USB dongle to the PC and press the S1 button. The LED D1 blinks every half second for ~5 sec. If the configuration is OK, the LED D1 at the end is ON.
2. Configure the HID mouse device (by resetting the board by keeping the S1 button pressed for less than 5 seconds).
3. Start the pairing procedure by pressing the S1 button on both boards. LED D1 blinks every 100 msec until the pairing procedure ends.

Both boards are now configured and paired and you should be able 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 will move the mouse down
- Tilting towards the ceiling will move the mouse up
- Tilting left will move the mouse left
- Tilting right will move the mouse right

The ZID RF4CE demo puts the mouse device in deep sleep after 5 seconds of inactivity. To wake up the mouse, push any button.

6 ZID, ZRC demonstration application

This is a demonstration application, based on the RF4CE ZRC & ZID application profile. It shows the coexistence between the two ZigBee RF4CE ZRC and ZID application profiles.

6.1 IAR project

This demonstration application shows the RF4CE ZID and ZRC application profile merged features, by using an HID device and a ZRC remote control. It requires 2 platforms:

- one configured as ZID RF4CE MEMS mouse device and ZRC
- one configured as USB RF4CE ZID host

The remote control only supports the channel +/- and the volume +/-. This demonstration application is PC-based.

6.2 Jumper settings

Table 13. Jumper settings

Jumper name	Role	STM32W108
JP1, if available	MOUSE_RC	Fitted
	HOST	Does not matter
	MOUSE_RC, HOST	MOUSE, HOST 1-2 (battery) 5-6 (USB)

6.3 Boards supported

Table 14. Boards supported

Board name	Board revision	ROLE	STM32W108xB	STM32W108CC
MB851	A,B	HOST	-	NA
	A,B	MOUSE_RC	-	NA
	C	HOST	X	NA
	C	MOUSE_RC	-	NA
	D	HOST	NA	X
	D	MOUSE_RC	NA	-
MB954	A	HOST	-	NA
	A	MOUSE_RC	-	NA
	B	HOST	X	NA
	B	MOUSE_RC	-	NA
	C	HOST	NA	X
	C	MOUSE_RC	NA	-
MB950A + MB953	MB953A	HOST, MOUSE_RC	X	NA
MB950A + MB953	MB953B	HOST, MOUSE_RC	NA	X
MB951	A	HOST	X	NA
	A	MOUSE_RC	-	NA
	B	HOST	NA	X
	B	MOUSE_RC	NA	-

X = supported

- = not supported

NA = not applicable

6.4 LED description

(MB950 + M953 configured with ZigBee RF4CE ZID_ZRC application)

Table 15. LED description

LED	Role	STM32W108
D1	RC	Turned ON
	MOUSE	Blinks each time a device does something and sends an RF packet
D3	RC	Not used
	MOUSE	Not used

6.5 Button description

(MB950 + M953 configured with ZigBee RF4CE ZID_ZRC application)

Table 16. Button description

Button	Role	STM32W108	Note
S1	RC	Volume +	Only related ZRC code is displayed
	MOUSE	Left key on mouse	
S2	RC	Volume -	Only related ZRC code is displayed
	MOUSE	Left key on mouse	
S3	RC	Channel -	Only related ZRC code is displayed
	MOUSE	Right key on mouse	
S4	RC	Channel +	Only related ZRC code is displayed
	MOUSE	Right key on mouse	
S5	RC or MOUSE	Switch device from Mouse to RC mode and vice versa.	LED D1 turned ON in RC mode. LED D1 blinks each time the mouse does something.

6.6 Set-up MEMS mouse device + RC platform

1. Download the zid_zrc firmware on the selected board.
2. CONFIGURE ZID RF4CE MOUSE DEVICE AND DELETE THE PAIRING TABLE:
   - Reset the board with the button S1 pressed.
   - When you release the button S1, you can see the LED D1 (green LED) flash twice to indicate that the command was executed.
3. PAIR MOUSE DEVICE WITH HOST DEVICE
   - Press S1.

Note: The mouse and RC will go to deep sleep after five seconds of no movement or buttons events. To wake up the mouse, please press any buttons or reset.

Other button commands (not normally needed):

4. UNCONFIGURE ZID RF4CE MOUSE DEVICE:
   – Reset the board with the button S1 pressed and keep the button S1 pressed for at least 5 seconds.
   – When you see the LED D1 flash twice, you can release the button S1. At this step, the board will be unconfigured.
5. RESET the board:
   – If you reset the board without any button pressed, the board will not lose its configuration.

6.7 Set up the HOST platform

1. Download the zid_zrc firmware on the selected board.
2. CONFIGURE ZID RF4CE HOST
   – After reset, press the button S1. You can see the LED D1 flash every half second for 5 sec. If the configuration ends with SUCCESS, the LED D1 will remain on; otherwise, it will remain off.
3. PAIRING PROCEDURE:
   – Press the button S1 on the ZID RF4CE Mouse board and on the ZID RF4CE Host board: the LED D1 will start blinking during the pairing procedure. If the procedure ends with SUCCESS, the ZID RF4CE Host notifies the mouse device connected to the PC and you will be able to use the mouse board like a pointer, with the right and left buttons.

Other button commands (not normally needed):

4. DELETE PAIRING TABLE ON ZID RF4CE HOST:
   – Press the S1 button for a couple of seconds. When the LED D1 is off, the device has the pairing table deleted.

6.8 How mouse and RC modes work

Button S5 is used to switch from Mouse to RC mode and vice versa.

Mouse mode

A mouse movement will be detected by the on-board MEMS. Tilt the mouse in a direction, and the speed of the mouse will be proportional to the tilt angle. In particular:

- Tilting towards the ground will move the mouse down
- Tilting towards the ceiling will move the mouse up
- Tilting left will move the mouse left
- Tilting right will move the mouse right

Press button S1 or S2 to emulate a click on the mouse left key.

Press button S3 or S4 to emulate a click on the mouse right key.

RC mode

The following RC standard commands are emulated through the platform buttons:

Press button S1 to emulate the VOL+ command.

Press button S2 to emulate the VOL- command.

Press button S4 to emulate the CH+ command.

Press button S3 to emulate the CH- command.

7 Using the STRF4CE library in Coprocessor mode

It is also possible to use an STM32W in an RF4CE network as a slave device driven by an external microcontroller, that acts as a host via a serial communication connection.

This Coprocessor mode is useful when the RF4CE target is a device which already has a microcontroller. For example, a TV, STB or DVD player.

7.1 Serial protocols

7.1.1 SPI protocol

The STM32W uses the Serial Peripheral Interface (SPI) for data communication as well as for handshake signaling using certain GPIOs.

The STM32W is configured as an SPI slave controller and uses four signals:

- **MOSI** (Master Out, Slave In): input data from master.
- **MISO** (Master In, Slave Out): output data sent to the master.
- **SCLK** (Serial Clock): clock data transfers on MOSI and MISO.
- **nSSEL** (Slave Select): the host uses this signal to enable serial communication with the slave.

In addition, three GPIO signals are used to manage the flow control between the host MCU and the STM32W:

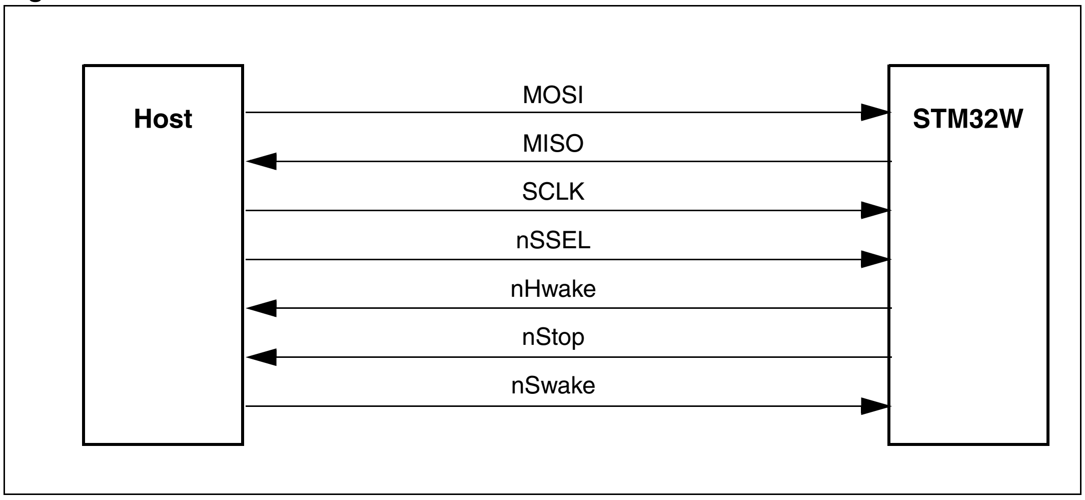
- **nSwake** used to wake up the STM32W when the host wants to start a communication.
- **nHwake** used to inform the host MCU that the STM32W has data available.
- **nStop,** when asserted by the STM32W, to signal to the host that it is busy for internal operations and that the host should stop the data transmission.

Table 17 lists the signals and the corresponding pin numbers for an STM32W device.

Table 17. SPI signal and pin information

Signal	GPIO	Direction	STM32W 48-pin package pin number	STM32W 40-pin package pin number
MISO	PA1	Output	22	18
MOSI	PA0	Input	21	17
SCLK	PA2	Input	24	20
nSSEL	PA3	Input	25	21
nHwake	PB3	Output	19	15
nSwake	PB4	Input	20	16
nStop	PA4	Output	26	22

Figure 9. Host connection in SPI mode



Note: The STM3W SPI channel configured in slave mode can support a data transfer rate of up to 5 Mbps.

7.1.2 UART protocol

The universal asynchronous receiver/transmitter (UART) protocol uses the following signals to exchange data between the host MCU and the STM32W:

- **TXD** data transmission pin
- **RXD** data reception pin

In addition, three other GPIO signals can be used to manage the flow control between the host MCU and the STM32W:

- **nSwake** to wake up the STM32W when the host wants to start a communication.
- **nHwake** to inform the host MCU that the STM32W has data available.
- **nStop,** when asserted by the STM32W, to signal to the host that it is busy for internal operation and that the host stops the data transmission.

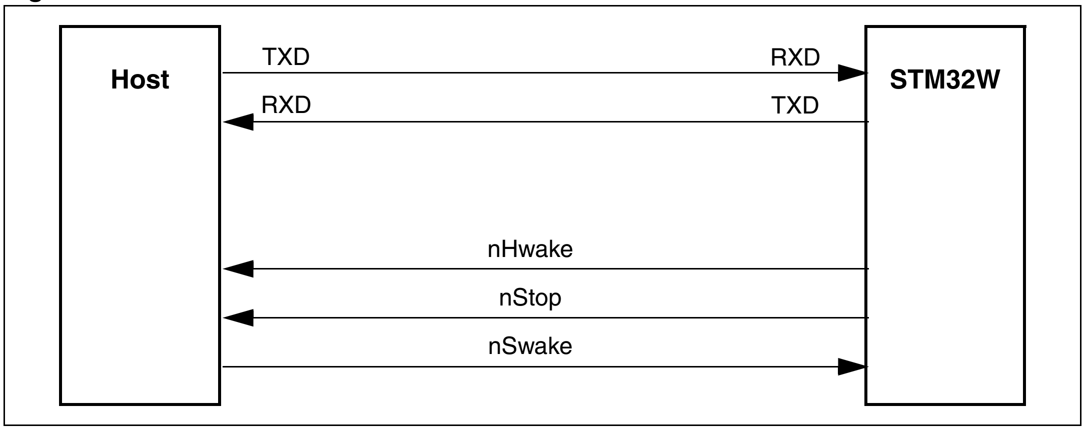
The UART uses the following set: 115200-8-None-1-None.

Table 18 lists the signals and the corresponding pin numbers for an STM32W device.

Table 18. UART signal and pin information

Signal	GPIO	Direction	STM32W 48-pin package pin number	STM32W 40-pin package pin number
TXD	PB1	Output	30	25
RXD	PB2	Input	31	26
nHwake	PB3	Output	19	15
nSwake	PB4	Input	20	16
nStop	PA4	Output	26	22

Figure 10. Host connection in UART mode



7.2 Packet format

Figure 11 shows the packet format used to exchange information between the host MCU and the STM32W using the SPI or UART protocol.

Figure 11. Packet format

Start Byte	Length Byte	Payload	End Byte

Where:

- **Start Byte**: packet type: command, response (1 byte length). Codes are:
  - **0xC0**: RF4CE command packet
  - **0xC1**: RF4CE response packet
- **Length Byte**: payload length not including End Byte (1 byte length)
- **Payload**: depends on the Start Byte, it has the following format:
  - **Command packet** (0xC0)

    The first byte is an RF4CE instruction code. Following bytes are instruction parameters, if any. The parameters are sent as a packed stream of bytes in little endian format.
  - **Response packet** (0xC1)

    All response bytes
- **End Byte**: Packet end with code **0xFC** (1 byte length)

The maximum packet length is 200 bytes. Therefore, the maximum payload is 197 bytes (including the 1 byte command packet and 196 bytes of parameters).

7.3 Serial RF4CE command codes

Table 19 lists all the RF4CE command codes used in the serial packet during communication.

Table 19. RF4CE coprocessor command codes

Command	Code	Description
NWKCOP_NOP	0x00	Nop instruction.
NWKCOP_NLDE_DATA_REQUEST	0x01	Data request function serial code.
NWKCOP_NLDE_DATA_INDICATION	0x02	Data indication function serial code.
NWKCOP_NLDE_DATA_CONFIRM	0x03	Data confirm function serial code.
NWKCOP_NLME_AUTO_DISCOVERY_REQUEST	0x04	Auto discovery request function serial code.
NWKCOP_NLME_AUTO_DISCOVERY_CONFIRM	0x05	Auto discovery confirm function serial code.
NWKCOP_NLME_COMM_STATUS_INDICATION	0x06	Comm status indication function serial code.
NWKCOP_NLME_DISCOVERY_REQUEST	0x07	Discovery request function serial code.
NWKCOP_NLME_DISCOVERY_INDICATION	0x08	Discovery indication function serial code.
NWKCOP_NLME_DISCOVERY_RESPONSE	0x09	Discovery response function serial code.
NWKCOP_NLME_DISCOVERY_CONFIRM	0x0A	Discovery confirm function serial code.
NWKCOP_NLME_GET	0x0B	Get request function serial code.
NWKCOP_NLME_PAIR_REQUEST	0x0C	Pair request function serial code.
NWKCOP_NLME_PAIR_INDICATION	0x0D	Pair indication function serial code.
NWKCOP_NLME_PAIR_RESPONSE	0x0E	Pair response function serial code.
NWKCOP_NLME_PAIR_CONFIRM	0x0F	Pair confirm function serial code.
NWKCOP_NLME_RESET	0x10	Reset request function serial code.
NWKCOP_NLME_RX_ENABLE	0x11	RX enable request function serial code.
NWKCOP_NLME_SET	0x12	Set request function serial code.
NWKCOP_NLME_START_REQUEST	0x13	Start request function serial code.
NWKCOP_NLME_START_CONFIRM	0x14	Start confirm function serial code.
NWKCOP_NLME_UNPAIR_REQUEST	0x15	Unpair request function serial code.
NWKCOP_NLME_UNPAIR_INDICATION	0x16	Unpair indication function serial code.
NWKCOP_NLME_UNPAIR_RESPONSE	0x17	Unpair response function serial code.
NWKCOP_NLME_UNPAIR_CONFIRM	0x18	Unpair confirm function serial code.
NWKCOP_NLME_UPDATE_KEY	0x19	Update key request function serial code.
NWKCOP_NWK_INIT	0x1A	Init the RF4CE network.
NWKCOP_MAC_GET_EUI64	0x1B	Get the IEEE Address.

Table 19. RF4CE coprocessor command codes (continued)

Command	Code	Description
NWKCOP_FIRMWARE_VERSION	0x1C	Get the firmware version. The information is 2 bytes; 0xyz 0kji, where x, y and z are the major, minor and patch versions for the network coprocessor firmware. k, j, and i are the major, minor and patch versions for RF4CE library.
NWKCOP_POWER_DOWN	0x1D	Power down request for STM32W coprocessor.
NWKCOP_POWER_UP	0x1E	Power up request for STM32W coprocessor.
NWKCOP_NWK_CONFIG	0x1F	Helper function request to configure RF4CE network coprocessor layer prior to cold start initialization.
NWKCOP_NVM_ERASE	0x20	Support function call to erase the RF4CE NVM network coprocessor memory.
NWKCOP_MAC_SET_EUI64	0x21	Set the IEEE Address only for test not available for normal use.

All the commands have a 4-byte response code to indicate the command outcome.

7.4 RF4CE serial communication code

The serial communication code is a byte sent after each communication which allows the host microcontroller and STM32W to check for errors during the last transaction. The codes are described in *Table 20*.

Table 20. Serial communication error codes

Command	Code	Description
NWKCOP_PACKET_TOO_LONG	0x1000 00DA	Serial communication error packet too long.
NWKCOP_PACKET_DAMAGED	0x1000 00DB	Serial communication error packet damaged.
NWKCOP_BUSY	0x1000 00DE	Serial communication error STM32W is busy form more than a timeout.
NWKCOP_UNKNOWN_COMMAND	0x1000 00CB	Serial communication error unknown command.
NWKCOP_UNKNOWN_PACKET_TYPE	0x1000 00CA	Serial communication error unknown packet type (start byte unknown).
NWKCOP_WRONG_PARAM_LENGTH	0x1000 00C9	Serial communication error wrong parameters length.
NWKCOP_END_PACKET_MISSING	0x1000 00C8	Serial communication error wrong parameters length-end byte missing.

These serial response codes are different from the return codes of the RF4CE function calls.

7.5 Physical level protocol

The following figures provide a graphical representation of a low-level protocol. They explain how signals are managed during communication.

Figure 12 shows an example of signal management during a serial communication started from the host side.

Figure 12. Serial communication started by the host (host side)

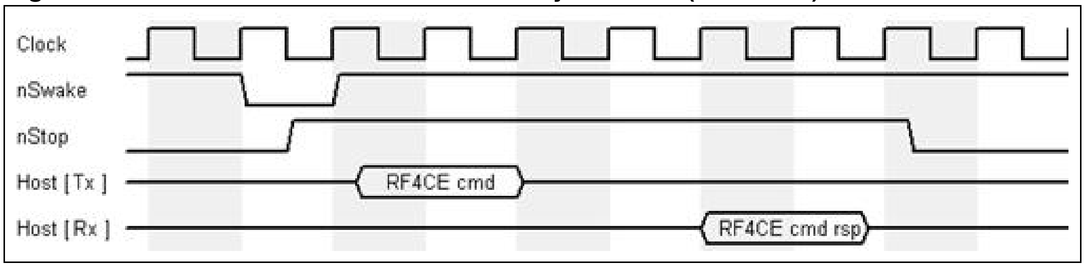
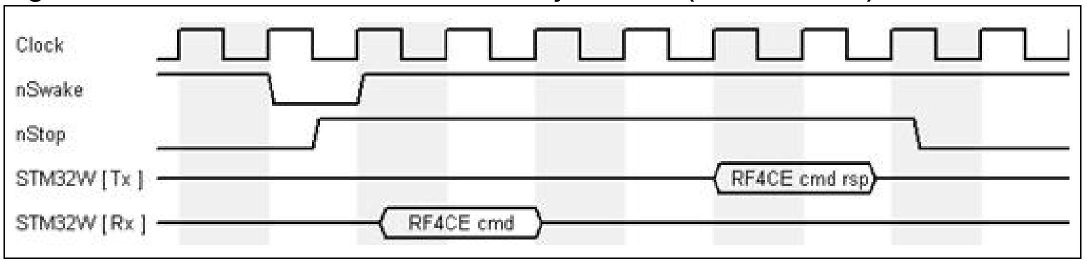


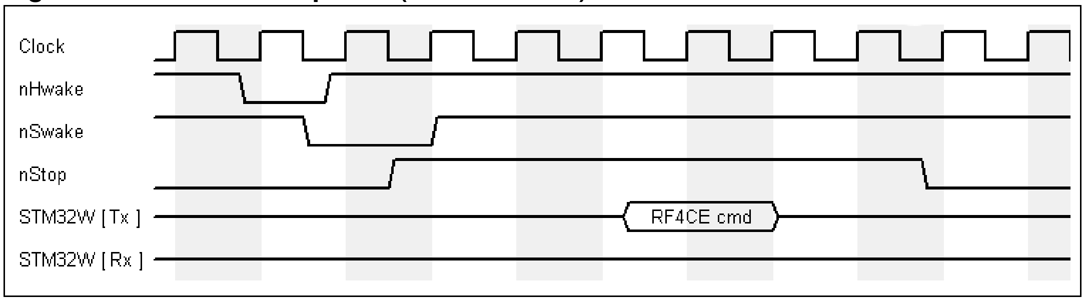
Figure 13 shows the low-level protocol from the STM32W side.

Figure 13. Serial communication started by the host (STM32W side)



If the STM32W starts a serial communication following an interrupt for a packet received, the low-level protocol is as shown in *Figure 14*.

Figure 14. Callback response (STM32W side)



7.6 Serial communication packet format example

The following examples show an example of byte sequences in packets during serial communication.

When the host launches a network init request `nwk_Init(0xf, 1)`, the packet has the following format:

C0	03	1A 0F 01	FC

Where:

0xC0 = command packet start byte

0x03 = payload length

0x1A = network init code

0x0F = node capabilities

0x01 = force cold start

0xFC = end packet

The STM32W executes the command and returns the following packet response:

C1	00 00 01 00	FC

Where:

0xC1 = command response start byte

0x00000100 = command response (RF4CE SAP pending)

0xFC = end packet

When the `start_confirm` callback function is received, the STM32W sends the following packet to the host MCU:

C0	05	14 00 00 00 00	FC

Where:

0xC0 = command packet start byte

0x05 = payload length

0x14 = start confirm command code

0x00000000 = status ok

0xFC = end packet

7.7 Software code structure

This section briefly describes the software structure for both communication sides: the network coprocessor and the host processor.

The network coprocessor runs a stand-alone application that basically consists of two state machines:

- `receiveStateMachine()` manages the RF4CE commands received from the host processor, translates the bytes and then calls the RF4CE primitive.
- `sendStateMachine()` manages the response command packets to send to the network coprocessor. It also picks up the messages received from the air and translates them as a byte sequence to send to the host processor using a serial connection.

As explained above, the network coprocessor can manage two different types of serial communications: SPI or UART. The user selects the SPI or UART interface during the compilation time using a special preprocessor define. If the user declares the preprocessor define `SC_SPI`, the network coprocessor manages the serial communication using the SPI channel in slave mode. Otherwise, if the preprocessor variable is not defined, the coprocessor uses the UART channel by default.

The host processor firmware is the interface between the user application and the network coprocessor. It manages RF4CE requests from the user application and translates them as a byte array to be sent through the serial channel.

The first step to execute in the `main()` is to initialize the serial communication UART or SPI using the command `hostSerialInit()`. After this initialization, the user application can execute the RF4CE commands.

Every RF4CE command is implemented using the following structure:

```
rf4ce_command (param)
{
   /* function to copy the rf4ce param values inside a byte array */
   cmd = create_array_byte_from_param (param)
   /* send the packet bytes through the serial channel */
   status = sendHostCmd (cmd)
   if (status == SUCCESS)
   /* wait the command response */
     status = waitRspCmd(rsp)
   if (status == SUCCESS)
     memcpy(&status, &rsp[2], 4)
   return status
}
```

The first step is to format the command param structure into a byte array according to the packet format displayed above.

The `sendHostCmd()` function sends the packet bytes using the UART or SPI protocol according to the `serialInit()` initialization function. This function also manages the GPIO signals used to regulate the flow control before starting the communication (see the figures in *Section 7.5: Physical level protocol*).

Every RF4CE command returns a 4-byte response that indicates the command result. The `waitRspCmd()` function waits for the result from the coprocessor and returns the value to the application.

A library for STM32F devices that interface with the STM32W and RF4CE coprocessor firmware is provided as an example. The library and the associated demo are intended to be run on an MB525 board fitted with an STM32F103VET6 microcontroller, but can be customized and adapted to different boards and microcontrollers.

The *rf4ce_cmds.c* file manages all the RF4CE commands from the host side, while the serial communication is managed by the *stm32_sc.c* file.

The RF4CE API provided to the host is described in Document [5].

7.8 RF4CE network coprocessor demo

The software demo highlights the same functions as those described in *Section 4* as well as how to work using an STM32W as the RF4CE network coprocessor.

The following boards are used to execute the demo:

- MB525 with STM32F103VET6 processor (host board)
- MB851 or MB954 with the STM32W108 processor (coprocessor board)

7.8.1 Building the firmware

The firmware for the MB525 board can be built from the IAR Embedded Workbench sources, using the related IAR project file. Please note that the firmware on the host MCU will be built for the UART interface by default.

The firmware running on the coprocessor board is only provided prebuilt and can be found in the *prebuilt* directory.

7.8.2 Programming the firmware

To program the STM32F firmware, you can use the IAR Embedded Workbench.

To program the STM32W prebuilt coprocessor firmware, please use the *stm32w_flasher.exe* file and follow the instructions provided in *Section 4.3*.

7.8.3 Setting up the boards

To run the demo, additional wiring between the host and the RF4CE coprocessor is required. *Table 21* provides information on the appropriate pins to connect on both boards. If you use the default firmware on the host, connect the pins marked ‘Yes’ in the UART column.

Table 21. Coprocessor board to MB525 connection with UART and SPI mode

Signal	Coprocessor board P1 connector	MB525 GPIO connector	UART	SPI
nHWake	5	PE10	Yes	Yes
nSWake	6	PE11	Yes	Yes
nStop	10	PE12	Yes	Yes
MOSI	7	PB15	No	Yes
MISO	8	PB14	No	Yes
SCLK	9	PB13	No	Yes
nSSEL	11	PE13	No	Yes
UART-RX	16	PD5	Yes	No
UART-TX	15	PD6	Yes	No
GND	22	GND	Yes	Yes

The demo uses the MB525 USART1 with settings as specified in *Table 6*.

The LED3 on the MB525 is the “heartbeat” LED and it blinks every half second.

The LED1 is an application LED with the following meaning:

- **ON** demo configured as TARGET
- **OFF** demo configured as CONTROLLER, or UNCONFIGURED
- **BLINKING every half second**, the board is initialized as TARGET and executing the energy-scan and active-scan, to select the channel and the PANID, respectively
- **BLINKING every 100 msec,** the device is executing a Discovery&Pair procedure

An IAR project is provided to show the network coprocessor reference code for the host side.

See *Section 4.4* for details on how to operate the demo.

8 Reference documents

[1] ZigBee RF4CE Specification, ZigBee Alliance document 094945r00ZB, Version 1.00, March 17th, 2009.

[2] ZigBee RF4CE: CERC Profile Specification, ZigBee Alliance document 094946r00ZB, March 17th, 2009.

[3] High-Definition Multimedia Interface Specification, HDMI Licensing, LLC, Version 1.3a, 5 November 10, 2006.

[4] STMicroelectronics, STM32W108HB datasheet, Doc ID 16252 Rev 3, December 2009

[5] ST RF4CE API Reference Guide, HTML document

[6] ZigBee RF4CE ZID Profile version 0.9, ZigBee Alliance document 105557r11cZB March 8th, 2011

9 Terms and definitions

Table 22. List of terms

Term	Meaning
ACK	Acknowledgment
API	Application programming interfaces
ZRC	ZigBee Remote Control
HDMI	High-Definition Multimedia Interface
MAC	Medium Access Control
NLDE	Network layer data entity
NLME	Network layer management entity
NVM	Non volatile memory
PAN	Personal Area Network
PHY	Physical layer
RC	Remote control device
RF4CE	Radio Frequency for Consumer Electronics
SAP	Service Access Point
ZID	ZigBee Input Device

10 Revision history

Table 23. Document revision history

Date	Revision	Changes
19-Feb-2010	1	Initial release.
31-Aug-2010	2	Added *Section 7: Using the STRF4CE library in Coprocessor mode*.
12-May-2011	3	Added *Section 5: ZID demonstration application*
31-Aug-2012	4	Updated User Manual for new ZigBee RF4CE release including: - replacement of *Figure 7* and *Figure 8* - update of *Table 11* - add-up of *Section 6: ZID, ZRC demonstration application*