S110 nRF51

Bluetooth® low energy Peripheral SoftDevice

SoftDevice Specification v2.0

Key Features

- *Bluetooth*® 4.1 compliant low energy single-mode protocol stack
    - Link layer
    - L2CAP, ATT, and SM protocols
    - GATT, GAP, and L2CAP
    - Concurrent Peripheral and Broadcaster roles
    - GATT Client and Server
    - Full SMP support including MITM and OOB pairing
- Complementary nRF51 SDK including *Bluetooth* profiles and example applications
- Master Boot Record for over-the-air device firmware update
- Memory isolation between application and protocol stack for robustness and security
- Thread-safe supervisor-call based API
- Asynchronous, event-driven behavior
- No RTOS dependency
    - Any RTOS can be used
- No link-time dependencies
    - Standard ARM® Cortex™-M0 project configuration for application development
- Support for multiprotocol operation concurrent with *Bluetooth* low energy connections and non-concurrently
    - Concurrent multiprotocol timeslot API
    - Alternate protocol stack running in application space

Applications

- Computer peripherals and I/O devices
    - Mouse
    - Keyboard
    - Multi-touch trackpad
- Interactive entertainment devices
    - Remote control
    - 3D glasses
    - Gaming controller
- Personal Area Networks
    - Health and fitness sensor and monitor devices
    - Medical devices
    - Key fobs and wrist watches
- Remote control toys
- Home automation

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Document Status

Status	Description
v0.5	This specification contains target specifications for product development.
v0.7	This specification contains preliminary data; supplementary data may be published from Nordic Semiconductor ASA later.
v1.0	This specification contains final product specifications. Nordic Semiconductor ASA reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.

Revision History

Date	Version	Description
February 2015	2.0	Updated for S110 SoftDevice v8.0.0. **Added:** • ***Chapter 6 "SoftDevice information structure"*** on page 14 • ***Section 11.1 "Attribute Table size"*** on page 33 • ***Appendix A "SoftDevice architecture"*** on page 50 **Updated:** • ***Section 3.1 "Profile and service support"*** on page 8 • ***Section 3.2 "Bluetooth low energy features"*** on page 9 • ***Chapter 8 "Radio Notification"*** on page 16 • ***Section 10.2 "Bootloader"*** on page 30 • ***Section 10.3 "Master Boot Record (MBR) and SoftDevice reset behavior"*** on page 31 • ***Section 10.4 "Master Boot Record (MBR) and SoftDevice initialization"*** on page 32 • ***Section 11.2 "Memory resource map and usage"*** on page 34 • ***Section 12.3 "BLE peripheral performance"*** on page 41 • ***Chapter 13 "BLE data throughput"*** on page 44 • ***Chapter 14 "BLE power profiles"*** on page 45
June 2014	1.3	Updated for S110 SoftDevice v7.0.0. **Added:** • ***Chapter 11.7 "External requirements"*** on page 38 **Updated:** • Key Features on front page • ***Section 1.1 "Documentation"*** on page 5 • ***Section 2.2 "Multiprotocol support"*** on page 6 • ***Section 3.1 "Profile and service support"*** on page 8 • ***Section 3.2 "Bluetooth low energy features"*** on page 9 • ***Chapter 4 "SoC library"*** on page 12 • ***Chapter 5 "SoftDevice Manager"*** on page 13 • ***Chapter 7 "Flash memory API"*** on page 15 • ***Section 9.6 "Multiprotocol timeslot API"*** on page 22 • ***Section 9.1 "Master Boot Record (MBR)"*** on page 30 • ***Section 11.2 "Memory resource map and usage"*** on page 34

Date	Version	Description
April 2014	1.3A	Updated for S110 SoftDevice v7.0.0. alpha **Added:** • ***Chapter 9 “Concurrent Multiprotocol Timeslot API”*** on page 20 • ***Section 9.1 “Master Boot Record (MBR)”*** on page 30 **Updated:** • Key Features on front page • ***Section 2.2 “Multiprotocol support”*** on page 6 • ***Table 3 “GAP features in the BLE stack”*** on page 9 • ***Table 9 “Proprietary features in the BLE stack”*** on page 11 • ***Table 26 “Additional latency due to SoftDevice and MBR processing”*** on page 39 • ***12.4 “Performance with Flash memory API and Concurrent Multiprotocol Timeslot API”*** on page 43
November 2013	1.2	Updated for S110 v6.0.0 release. Added ***Chapter 7 “Flash memory API”*** on page 15; Added ***Chapter 10 “Master Boot Record and Bootloader”*** on page 30 Updated ***Table 1*** on page 8; Updated ***Table 4*** on page 10; Updated ***Table 10*** on page 12; Updated ***Chapter 8 “Radio Notification”*** on page 16; Updated ***Table 17*** on page 19.
March 2013	1.1	Updated for changes made as of S110 v5.0.0; Changed ***Section 9.2 “Processor availability”*** on page 37 and ***Section 14 “BLE power profiles”*** on page 45; Changed ***Table 27*** on page 37; Added ***Table 28*** on page 38; Changed ***Table 30*** on page 40; Changed ***Figure 16*** on page 46 and ***Figure 17*** on page 47.
February 2013	1.0	Changed Memory resource requirements in ***Table 16*** on page 19; Added ***Section 9.3 “Application signals - software interrupts”*** on page 21; Updated ***Chapter 9 “BLE performance”*** on page 36 and added ***Section 9.3 “Data throughput”*** on page 40; Updated diagrams in ***Chapter 14 “BLE power profiles”*** on page 45; Added ***Chapter 15 “SoftDevice identification and revision scheme”*** on page 48; Updated ***Chapter 15.2 “Notification of SoftDevice revision updates”*** on page 49.
September 2012	0.6	First release.

1 Introduction

The S110 SoftDevice is a *Bluetooth*® low energy (BLE) Peripheral protocol stack solution. It integrates a low energy controller and host, and provides a full and flexible Application Programming Interface (API) for building *Bluetooth* low energy System on Chip (SoC) solutions.

This document contains information about the SoftDevice features and performance.

> **Note:** The SoftDevice features and performance are subject to change between revisions of this document. See ***Section 15.2 "Notification of SoftDevice revision updates"*** on page 49 for more information. This specification outlines the supported features of a production level SoftDevice. Alpha and beta versions of the SoftDevice may not support all features. To find information on any limitations or omissions, see the SoftDevice release notes, which will contain a detailed summary of the release status.

1.1 Documentation

Below is a list of the core documentation for the SoftDevice.

Document	**Description**
Appendix A: SoftDevice Architecture	Essential reading for understanding the resource usage and performance related chapters of this document.
nRF51822 Product Specification (PS)	Contains a description of the hardware, modules, and electrical specifications specific to the nRF51822 chip.
nRF51822 Product Anomaly Notification (PAN)	Contains information on anomalies related to the nRF51822 chip.
nRF51 Series Compatibility Matrix	Compatibility and relations between nRF51 IC revisions, SoftDevices and SoftDevice Specifications, SDKs, development kits, documentation, and QDIDs.
Bluetooth Core Specification	The *Bluetooth Core Specification* version 4.1, Volumes 1, 3, 4, and 6 describes *Bluetooth* terminology which is used throughout the SoftDevice Specification.

2 Product overview

This section provides an overview of the SoftDevice.

2.1 SoftDevice

The SoftDevice is a precompiled and linked binary software implementing a *Bluetooth* 4.1 low energy protocol stack for the nRF51 series of chips. See the nRF51 Series Compatibility Matrix for SoftDevice/chip compatibility information.

The Application Programming Interface (API) is a set of standard C language functions and data types that give the application complete compiler and linker independence from the SoftDevice implementation.

The SoftDevice enables the application programmer to develop their code as a standard ARM® Cortex™-M0 project without needing to integrate with proprietary chip-vendor software frameworks. This means that any ARM® Cortex™-M0 compatible toolchain can be used to develop *Bluetooth* low energy applications with the SoftDevice.

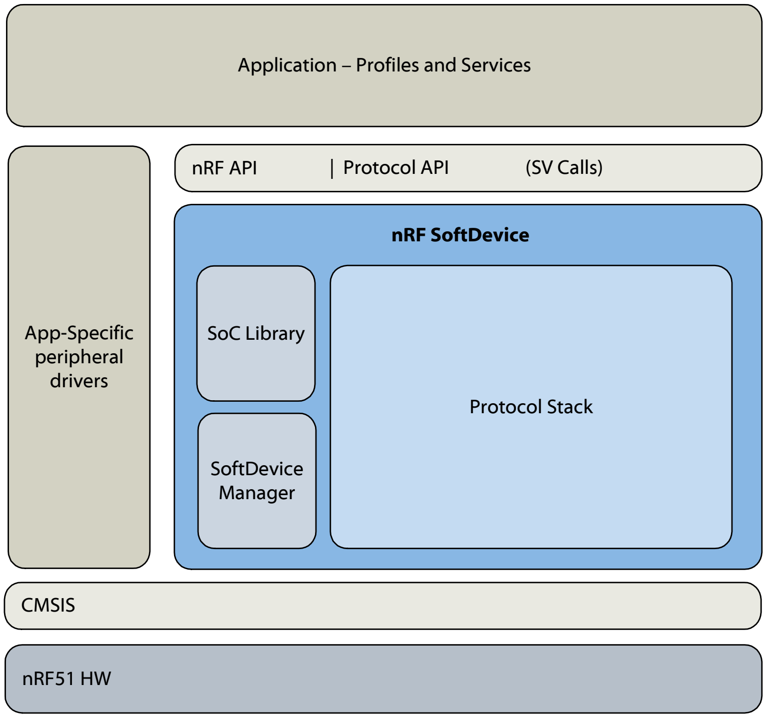


Figure 1 *System on Chip application with the SoftDevice*

The SoftDevice can be programmed onto compatible nRF51 Series chips during both development and production.

2.2 Multiprotocol support

The SoftDevice supports both non-concurrent and fully concurrent multiprotocol implementations. For non-concurrent operation, a proprietary 2.4 GHz protocol can be implemented in the application program area and can access all hardware resources when the SoftDevice is disabled. For concurrent multiprotocol operation, with a proprietary protocol running concurrently with the SoftDevice protocol(s), see ***Chapter 9 "Concurrent Multiprotocol Timeslot API"*** on page 20.

3 *Bluetooth* low energy protocol stack

The *Bluetooth* 4.1 compliant low energy Host and Controller embedded in the SoftDevice are fully qualified with multi-role support (Peripheral and Broadcaster). The API is defined above the Generic Attribute Protocol (GATT), Generic Access Profile (GAP), and Logical Link Control and Adaptation Protocol (L2CAP). The SoftDevice allows applications to implement standard *Bluetooth* low energy profiles as well as proprietary use case implementations.

The nRF51 Software Development Kit (SDK) complements the BLE protocol stack with Service and Profile implementations. Single-mode System on Chip (SoC) applications are enabled by the full BLE protocol stack and nRF51 series integrated circuit (IC).

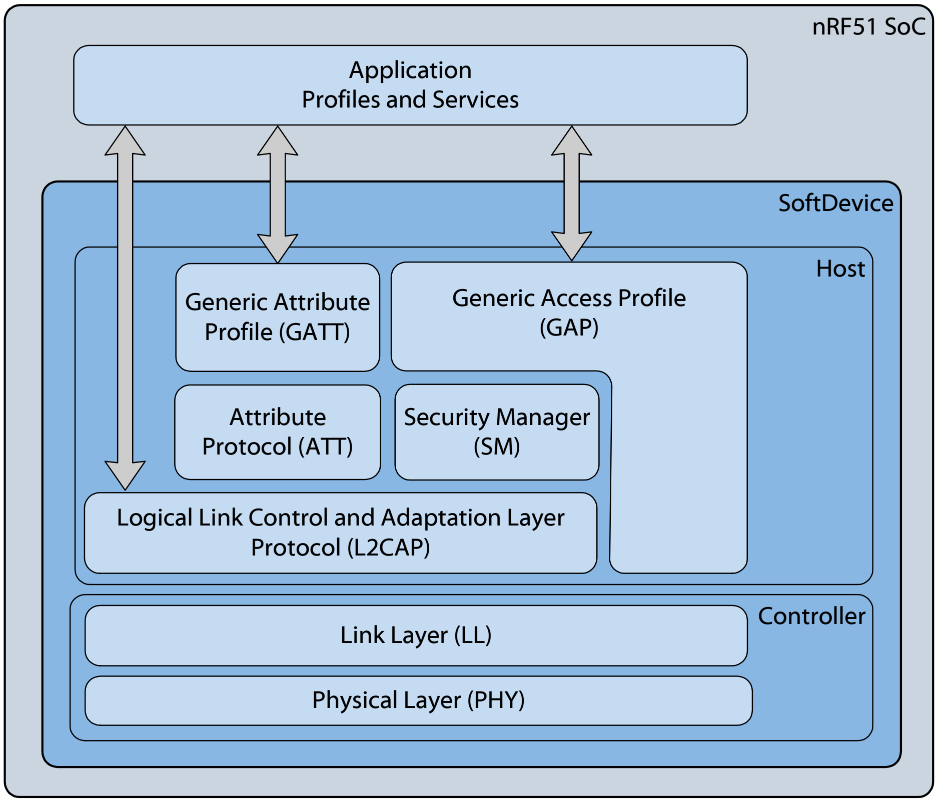


Figure 2 *SoftDevice stack architecture*

3.1 Profile and service support

Table 1 lists the profiles and services adopted by the *Bluetooth* Special Interest Group at the time of publication of this document. The SoftDevice supports all of these as well as additional proprietary profiles.

Adopted Profile	Adopted Services
HID over GATT	HID Battery Device Information
Heart Rate	Heart Rate Device Information
Proximity	Link Loss Immediate Alert TX Power
Blood Pressure	Blood Pressure Device Information
Health Thermometer	Health Thermometer Device Information
Glucose	Glucose Device Information
Phone Alert Status	Phone Alert Status
Alert Notification	Alert Notification
Time	Current Time Next DST Change Reference Time Update
Find Me	Immediate Alert
Cycling Speed and Cadence	Cycling Speed and Cadence Device information
Running Speed and Cadence	Running Speed and Cadence Device Information
Location and Navigation	Location and Navigation
Cycling Power	Cycling Power
Scan Parameters	Scan Parameters
Weight Scale	Weight Scale Body Composition User Data Device Information
Continuous Glucose Monitoring	Continuous Glucose Monitoring Bond Management Device Information
Environmental Sensing	Environmental Sensing

***Table 1** Supported profiles and services*

Note: Examples for selected profiles and services are available in the nRF51 SDK. See the SDK documentation for details.

3.2 *Bluetooth* low energy features

The BLE protocol stack in the SoftDevice has been designed to provide an abstract but flexible interface for application development for *Bluetooth* low energy devices. GAP, GATT, SM, and L2CAP are implemented in the SoftDevice and managed through the API. The SoftDevice implements GAP and GATT procedures and modes that are common to most profiles, such as the handling of discovery, connection, pairing, and bonding.

The BLE API is consistent across *Bluetooth* role implementations where common features have the same interface. The following tables describe the features found in the BLE protocol stack.

API Features	Description
Interface to: GATT/GAP/L2CAP	Consistency between APIs including shared data formats.
Attribute Table sizing, population, and access	Full flexibility to size the Attribute Table at application compile time and to populate it at runtime. Attribute removal is not supported.
Asynchronous and event driven	Thread-safe function and event model enforced by the architecture.
Vendor-specific (128 bit) UUIDs for proprietary profiles	Compact, fast, and memory efficient management of 128 bit UUIDs.
Packet flow control	Full application control over data buffers to ensure maximum throughput.

***Table 2** API features in the BLE stack*

GAP Features	Description
Multi-role: Peripheral and Broadcaster	Broadcaster can run concurrently with a peripheral in a connection.
Multiple bond support	Keys and peer information stored in application space. No restrictions in stack implementation.
Security mode 1: Levels 1, 2, and 3	Support for all levels of SM 1.
User-defined Advertising data	Full control over advertising and scan response data for the application.

***Table 3** GAP features in the BLE stack*

GATT Features	Description
Full GATT Server	Including configurable Service Changed Support
Support for authorization:	Enables control points Enables freshest data Enables GAP authorization
Full GATT Client	Flexible data management options for packet transmission with either fine control or abstract management
Implemented GATT Sub-procedures	Discover all Primary Services Discover Primary Service by Service UUID Find included Services Discover All Characteristics of a Service Discover Characteristics by UUID Discover All Characteristic Descriptors Read Characteristic Value Read using Characteristic UUID Read Long Characteristic Values Read Multiple Characteristic Values (Client only) Write Without Response Write Characteristic Value Notifications Indications Read Characteristic Descriptors Read Long Characteristic Descriptors Write Characteristic Descriptors Write Long Characteristic Values Write Long Characteristic Descriptors Reliable Writes

Table 4 *GATT features in the BLE stack*

Security Manager Features	Description
Flexible key generation and storage for reduced memory requirements	Keys are stored directly in application memory to avoid unnecessary copies and memory constraints.
Authenticated MITM (Man in the middle) protection	Allows for per-link elevation of the encryption security level.
Pairing methods: Just works, Passkey Entry, and Out of Band	API provides the application full control of the pairing sequences.

Table 5 *Security Manager (SM) features in the BLE stack*

ATT Features	Description
Server protocol	Fast and memory efficient implementation of the ATT server role.
Client protocol	Fast and memory efficient implementation of the ATT client role.
Max MTU size 23 bytes	Up to 20 bytes of user data available per packet.

Table 6 *Attribute Protocol (ATT) features in the BLE stack*

L2CAP Features	Description
Low level L2CAP API access	Ability to send arbitrary L2CAP data from the application.

Table 7 *Logical Link Control and Adaptation Layer Protocol (L2CAP) features in the BLE stack*

Controller, Link Layer Features	Description
Slave role	
Connection update	
Encryption	
RSSI	Signal strength measurements both during advertising and connection.

Table 8 *Controller, Link Layer (LL) features in the BLE stack*

Proprietary Feature	Description
TX Power control	Access for the application to change TX power settings anytime.
Enhanced Privacy 1.1 support	Synchronous and low power solution for BLE enhanced privacy with hardware-accelerated address resolution for whitelisting.
Master Boot Record (MBR) for Device Firmware Update (DFU)	Enables over-the-air SoftDevice replacement, giving full SoftDevice update capability.

Table 9 *Proprietary features in the BLE stack*

4 SoC library

The following features ensure that the Application and SoftDevice can coexist with safe sharing of common SoC resources.

Feature	Description
Mutex	The SoftDevice implements atomic mutex acquire and release operations that are safe for the application to use. Use this mutex to avoid disabling global interrupts in the application, because disabling global interrupts will interfere with the SoftDevice and may lead to dropped packets or lost connections.
NVIC	Gives the application access to all NVIC features without corrupting SoftDevice configurations.
Rand	Provides random numbers from the hardware random number generator.

Power	Access to POWER block configuration while the SoftDevice is enabled:
	• Access to RESETREAS register
	• Set power modes
	• Configure power fail comparator
	• Control RAM block power
	• Use general purpose retention register
	• Configure DC/DC converter state:
	  • DISABLED
	  • ENABLED

Clock	Access to CLOCK block configuration while the SoftDevice is enabled. Allows the HFCLK Crystal Oscillator source to be requested by the application.
Wait for event	Simple power management call for the application to use to enter a sleep or idle state and wait for an event.
PPI	Configuration interface for PPI channels and groups reserved for an application.
Concurrent Multiprotocol Timeslot API	Schedule other radio protocol activity, or periods of radio inactivity. See ***Chapter 9 "Concurrent Multiprotocol Timeslot API"*** on page 20.
Radio notification	Configure Radio Notification signals on ACTIVE and/or nACTIVE. See ***Chapter 8 "Radio Notification"*** on page 16.
Block encrypt (ECB)	Safe use of 128 bit AES encrypt HW accelerator.
Event API	Fetch asynchronous events generated by the SoC library.
Flash memory API	Application access to flash write, erase, and protect. Can be safely used during all protocol stack states. See ***Chapter 6 "Flash memory API"*** on page 15.
Temperature	Application access to the temperature sensor.

Table 10 *System on Chip features*

5 SoftDevice Manager

The following feature enables the Application to manage the SoftDevice on a top level.

Feature	Description
SoftDevice control API	Control of SoftDevice state through enable and disable. On enable, the low frequency clock source can be selected between the following options: • RC oscillator • Crystal oscillator

Table 11 *SoftDevice Manager*

6 SoftDevice information structure

The SoftDevice binary file contains an information structure. The structure is illustrated in ***Figure 3***.
The location of the structure, the SoftDevice size, and the firmware_id can be obtained at runtime by the application using macros defined in the nrf_sdm.h header file. (Accessing this structure requires that the SoftDevice is not read back protected.) The information structure can also be accessed by parsing the binary SoftDevice file.

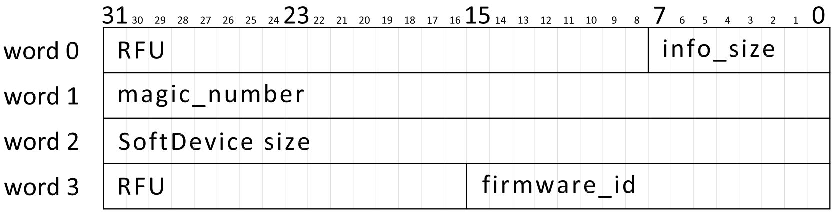


Figure 3 *SoftDevice information structure*

7 Flash memory API

Asynchronous flash memory operations are performed using the SoC library API and provide the application with flash write, flash erase, and flash protect support through the SoftDevice. This interface can safely be used during active BLE connections.

The flash memory access is scheduled in between the protocol radio events. For short connection or advertisement intervals, the time required for the flash memory access may be larger than the connection or advertisement interval. In this case, protocol radio events may be skipped, up to a maximum of three connection events or one advertisement event. The flash memory access may also be delayed slightly to minimize the disturbance of the BLE radio protocol. In some cases as described below, the flash memory access may fail and generate a timeout event: `NRF_EVT_FLASH_OPERATION_ERROR`. In this case, retry the flash erase or write operation.

BLE activity	Flash write
BLE Connectable Undirected Advertising BLE Nonconnectable Advertising BLE Scannable Advertising	Typically allows full write size (256 words) attempts, but shorter write sizes have higher probability of success.
BLE Connectable Directed Advertising	Does not allow write attempts while advertising is active (maximum 1.28 seconds). In this case, retrying flash writes will only succeed after the advertising activity has finished.
BLE Connected state	Typically allows full write size (256 words) attempts. May generate flash timeout event: `NRF_EVT_FLASH_OPERATION_ERROR` if critical radio events need to occur. Critical radio events are expected at connection setup, at connection update, at disconnection and just before supervision timeout. In this case, retry the flash write operation.
BLE activity	**Flash erase**
BLE Connectable Undirected Advertising BLE Nonconnectable Advertising BLE Scannable Advertising	Typically allows flash erase attempts.
BLE Connectable Directed Advertising	Does not allow flash erase attempts while advertising is active (maximum 1.28 seconds). In this case, retrying flash erase will only succeed after the directed advertising is finished.
BLE Connected state	Typically allows flash erase attempts. May generate flash timeout event: `NRF_EVT_FLASH_OPERATION_ERROR` if critical radio events need to occur. Critical radio events are expected at connection setup, at connection update, at disconnection and just before supervision timeout. In this case, retry the flash erase operation.

__Table 12__ Behavior with BLE traffic and concurrent flash write/erase

8 Radio Notification

Radio Notification is a configurable feature that enables ACTIVE and INACTIVE (nACTIVE) signals from the SoftDevice that notify the application when the radio is in use. The signal is sent using software interrupt, as specified in ***Table 23*** on page 37.

In order to make sure that the Radio Notification signals behave in a consistent way, Radio Notification shall always be configured when the SoftDevice is in an idle state with no protocol stack or other SoftDevice activity in progress. It is therefore recommended to configure the Radio Notification signals directly after the SoftDevice has been enabled.

The ACTIVE signal, if enabled, is sent before the Radio Event starts. The nACTIVE signal is sent at the end of the Radio Event. These signals can be used by the application programmer to synchronize application logic with radio activity. For example, the ACTIVE signal can be used to shut off external devices to manage peak current drawn during periods when the radio is on, or to trigger sensor data collection for transmission in the Radio Event.

Because both ACTIVE and nACTIVE use the same software interrupt, it is up to the application to manage them. If both ACTIVE and nACTIVE are configured ON by the application, there will always be an ACTIVE signal before an nACTIVE signal.

Figure 4 shows the active signal in relation to the Radio Event.

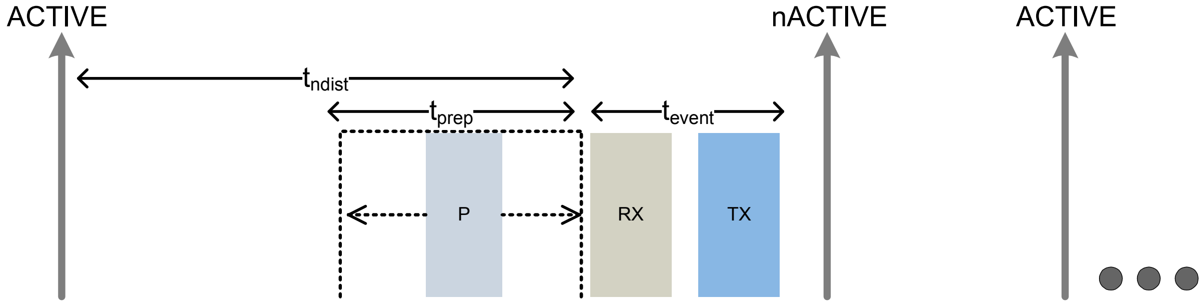


Figure 4 *BLE Radio Notification*

Many packets can be sent and received in one Radio Event. Radio Notification events will be as shown in ***Figure 5***.

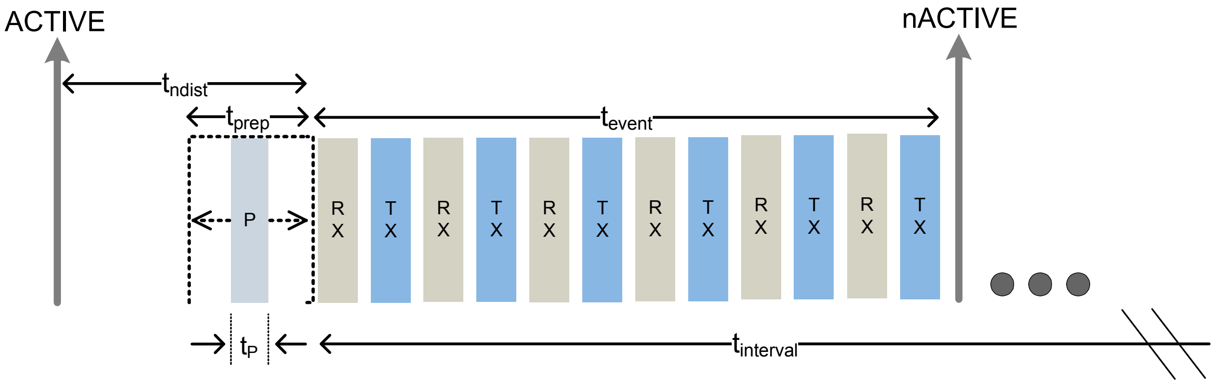


Figure 5 *BLE Radio Notification, multiple packet transfers*

Table 13 describes the notation used in ***Figure 4*** on page 16 and ***Figure 5*** on page 16.

Label	Description	Notes
ACTIVE	The ACTIVE signal prior to a Radio Event.	
nACTIVE	The nACTIVE signal after a Radio Event.	
P	CPU processing in the lower stack interrupt between t_{prep} and RX.	The CPU processing may occur anytime, up to t_{prep} before RX.
RX	Reception of packet.	
TX	Transmission of packet.	
t_{ndist}	The notification distance - the time between ACTIVE and first RX/TX in a Radio Event.	This time is configurable by the application developer and can be changed in between Radio Events.
t_{event}	The time used in a Radio Event.	
t_{prep}	The time before first RX/TX to prepare and configure the radio.	The application will be interrupted by the LowerStack during t_{prep}. **Note**: All packet data to send in an event should be sent to the stack t_{prep} before the Radio starts.
t_P	Time used for preprocessing before the Radio Event.	
$t_{interval}$	Time between Radio Events as per the protocol.	

Table 13 *Radio Notification figure labels*

Table 14 shows the ranges of the timing symbols in ***Figure 4*** on page 16. See also ***Table 15*** on page 19.

Value	Range (µs)
t_{ndist}	800, 1740, 2680, 3620, 4560, 5500
t_{event}	550 to 4850 - Undirected and scannable advertising, 0 to 31 byte payload, 3 channels 550 to 2250 - Non-connectable advertising, 0 to 31 byte payload, 3 channels 1.28 seconds - Directed advertising, 3 channels 900 to 5400 Slave - 1 to 6 packets RX and TX unencrypted data when connected 1000 to 5800 Slave - 1 to 6 packets RX and TX encrypted data when connected
t_{prep}	290 to 1550
t_P	≤150

Table 14 *BLE Radio Notification timing ranges*

Using the numbers from ***Table 14*** on page 17, the amount of CPU time available between ACTIVE and a Radio Event is:

$$t_{ndist} - t_P$$

Shown below is the amount of time before stack interrupts begin. Data packets must be transferred to the stack using the API within this time from the ACTIVE signal if they are to be sent in the next Radio Event.

$$t_{ndist} - t_{prep(maximum)}$$

Note: t_{prep} may be greater than t_{ndist} when $t_{ndist} = 800$. If time is required to handle packets or manage peripherals before interrupts are generated by the stack, t_{ndist} should be set greater than 1550.

To ensure the notification signal is available to the application at the configured time when a single link is established, the SoftDevice enforces the following rule (with one exception, see ***Table 15*** on page 19):

$$t_{ndist} + t_{event} < t_{interval}$$

The stack will limit the length of a Radio Event (t_{event}), thereby reducing the maximum packets exchanged, to accommodate the selected t_{ndist}. ***Figure 6*** shows consecutive Radio Events with Radio Notification and illustrates the limitation in t_{event} which may be required to ensure t_{ndist} is preserved.

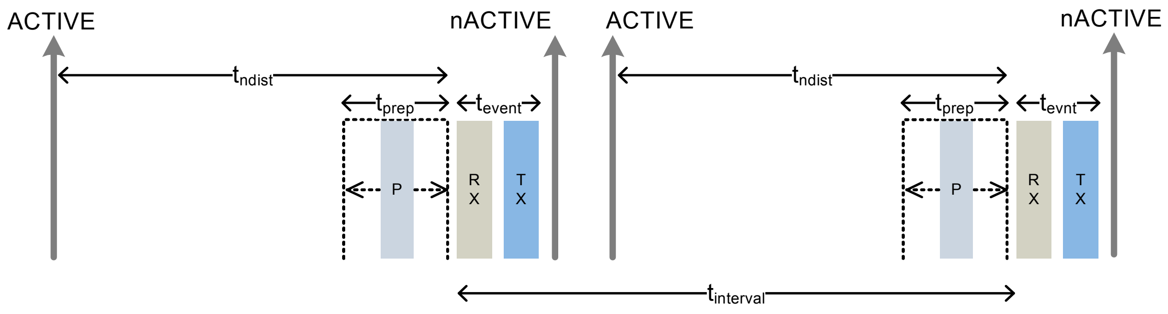


Figure 6 *Consecutive Radio Events with BLE Radio Notification*

Table 15 shows the limitation on the maximum number of full length packets which can be transferred per Radio Event given a t_{ndist} and $t_{interval}$ combination.

t_{ndist}	$t_{interval}$		
	7.5 ms	**10 ms**	**≥ 15 ms**
800	5	6	6
1740	4	6	6
2680	4	6	6
3620	3	5	6
4560	2	4	6
5500	0[1]	3	6

[1] Radio notifications may be suppressed with the longest t_{ndist} combined with a 7.5 ms connection interval.

Table 15 *Maximum packet transfer per BLE Radio Event for given combinations of* t_{ndist} *and* $t_{interval}$.

9 Concurrent Multiprotocol Timeslot API

The Multiprotocol Timeslot API allows an application developer to safely schedule 2.4 GHz proprietary radio usage while the SoftDevice protocol stack is in use by the device. This allows the nRF51 device to be part of a network using the SoftDevice protocol stack and an alternative network of wireless devices at the same time.

The Timeslot feature gives the application access to the radio and other restricted peripherals, which it does by queueing the application's use of these peripherals with those of the SoftDevice. Using this feature, the application can run other radio protocols (third party custom or proprietary protocols running from application space) concurrently with the internal protocol stack(s) of the SoftDevice. It can also be used to suppress SoftDevice radio activity and reserve guaranteed time for application activities with hard timing requirements which cannot be met by using the SoC Radio Notifications.

The Timeslot feature is part of the SoC library. The feature works by having the SoftDevice time-multiplex access to peripherals between the application and itself. Through the SoC API, the application can open a Timeslot session and request timeslots. When a timeslot is granted, the application has exclusive and real-time access to the normally blocked RADIO, TIMER0, CCM, AAR, and PPI (channels 14 – 15) peripherals and can use these freely for the length of the timeslot, see ***Table 21 “Hardware access type definitions”*** on page 35 and ***Table 22 “Peripheral protection and usage by SoftDevice”*** on page 36.

9.1 Request types

Timeslots may be requested as *earliest possible*, in which case the timeslot occurs at the first available opportunity. In the request, the application can limit how far into the future the timeslot may be placed. Timeslots may also be requested at a given time. In this case, the application specifies in the request when the timeslot should start and the time is measured from the start of the previous timeslot. Note that the first request in a session must always be *earliest possible* to create the timing reference point for later timeslots. The application may also request to extend an on-going timeslot. Extension requests may be repeated, prolonging the timeslot even further.

Timeslots requested as *earliest possible* are useful for single timeslots and for non-periodic or non-timed activity. Timeslots requested at a given time relative to the previous timeslot are useful for periodic and timed activities; for example, a periodic proprietary radio protocol. Timeslot extension may be used to secure as much continuous radio time as possible for the application; for example, running an “always on” radio listener.

9.2 Request priorities

Timeslots can be requested at either high or normal priority, indicating how important it is for the application to access the specified peripherals. Using normal priority should be considered best practice to minimize the influence of the use of the Multiprotocol Timeslot API on other activities. The high priority should only be used when required, such as for running a radio protocol with certain timing requirements that are not met using normal priority.

9.3 Timeslot length

The length of the timeslot is specified by the application in the request and ranges from 100 µs to 100 ms. Longer continuous timeslots can be achieved by requesting to extend the current timeslot. Successive extensions will give a timeslot as long as possible within the limits set by other SoftDevice activities, up to a maximum of 128 s.

9.4 Scheduling

Timeslots requested by the application are scheduled within the SoftDevice along with the SoftDevice protocol and the Flash API activities.

Whether the timeslot request is granted and access to the peripherals given is based on when the request was made, when the timeslot is wanted, the priority of the request, and the requested length of the timeslot. If the requested timeslot does not collide with other activities, the request will be granted and the timeslot scheduled. If the requested timeslot collides with an already scheduled activity with equal or higher priority, the request will be blocked. If a later arriving activity of higher priority causes a collision, the request will be canceled and the scheduled timeslot revoked. However, a timeslot that has already started cannot be interrupted or canceled. Timeslots requested at high priority will cancel other activities scheduled at lower priorities in case of a collision. Also, requests for short timeslots have a higher probability of succeeding than requests for longer timeslots because shorter timeslots are easier to fit into the schedule.

Note: Radio Notification signals behave the same way for timeslots requested through the Multiprotocol Timeslot interface as for SoftDevice internal activities, see ***Chapter 8 "Radio Notification"*** on page 16 for more information. If Radio Notifications are enabled, Multiprotocol Timeslots will be notified.

9.5 Performance considerations

Since the Multiprotocol Timeslot API shares core peripherals with the SoftDevice, and are scheduled along with other SoftDevice activities, use of the Timeslot feature may influence SoftDevice performance. Therefore the application configuration of the SoftDevice protocol should be considered when using the Multiprotocol Timeslot API.

In general, all timeslot requests should use the lowest priority to ensure that interruptions to other activity is minimized. In addition, timeslots should be kept as short as possible in order to minimize the impact on the overall performance of the device. Similarly, requesting a shorter timeslot and then extending it gives more flexibility to schedule other activities than requesting a longer timeslot.

9.6 Multiprotocol timeslot API

A Timeslot session is opened and closed using API calls. Within a session, there is an API call to request timeslots. For communication back to the application the feature will generate events, which are handled by the normal application event handler, and signals, which must be handled by a callback function (the signal handler) provided by the application. The signal handler can also return actions to the SoftDevice. Within a timeslot, only the signal handler is used.

Note: The API calls, events, and signals are only given by their full names in the tables where they are listed the first time. Elsewhere, only the last part of the name is used.

9.6.1 API calls

The following API calls are defined:

API call	Description
sd_radio_session_open()	Open a timeslot session.
sd_radio_session_close()	Close a timeslot session.
sd_radio_request()	Request a timeslot.

***Table 16** API calls*

9.6.2 Timeslot events

Events come from the SoftDevice scheduler and are used for timeslot session management. Events are received in the application event handler callback function, which will typically be run in App(L) priority, see ***Section 12.3 "BLE peripheral performance"*** on page 41.

The following events are defined:

Event	Description
NRF_EVT_RADIO_SESSION_IDLE	Session status: The current timeslot session has no remaining scheduled timeslots.
NRF_EVT_RADIO_SESSION_CLOSED	Session status: The timeslot session is closed and all acquired resources are released.
NRF_EVT_RADIO_BLOCKED	Timeslot status: The last requested timeslot could not be scheduled, due to a collision with already scheduled activity or for other reasons.
NRF_EVT_RADIO_CANCELED	Timeslot status: The scheduled timeslot was preempted by higher priority activity.
NRF_EVT_RADIO_SIGNAL_CALLBACK_INVALID_RETURN	Signal handler: The last signal hander return value contained invalid parameters.

***Table 17** Timeslot events*

9.6.3 Timeslot signals

Signals come from the peripherals and arrive within a timeslot. Signals are received in a signal handler callback function that the application must provide. The signal handler runs in LowerStack priority, which is the highest priority in the system, see ***Section 12.3 "BLE peripheral performance"*** on page 41.

Signal	Description
NRF_RADIO_CALLBACK_SIGNAL_TYPE_START	Start of the timeslot. The application now has exclusive access to the peripherals for the full length of the timeslot.
NRF_RADIO_CALLBACK_SIGNAL_TYPE_RADIO	Radio interrupt, for more information, see chapter *2.4 GHz radio (RADIO)* in the *nRF51 Reference Manual*.
NRF_RADIO_CALLBACK_SIGNAL_TYPE_TIMER0	Timer interrupt, for more information, see chapter *Timer/counter (TIMER)* in the *nRF51 Reference Manual*.
NRF_RADIO_CALLBACK_SIGNAL_TYPE_EXTEND_SUCCEEDED	The latest extend action succeeded.
NRF_RADIO_CALLBACK_SIGNAL_TYPE_EXTEND_FAILED	The latest extend action failed.

Table 18 *Timeslot signals*

9.6.4 Signal handler return actions

The return value from the application signal handler to the SoftDevice contains an action. The signal handler action return values are:

Return value	Description
NRF_RADIO_SIGNAL_CALLBACK_ACTION_NONE	The timeslot processing is not complete. The SoftDevice will take no action.
NRF_RADIO_SIGNAL_CALLBACK_ACTION_END	The current timeslot has ended. The SoftDevice can now resume other activities.
NRF_RADIO_SIGNAL_CALLBACK_ACTION_REQUEST_AND_END	The current timeslot has ended. The SoftDevice is requested to schedule a new timeslot, after which it can resume other activities.
NRF_RADIO_SIGNAL_CALLBACK_ACTION_EXTEND	The SoftDevice is requested to extend the ongoing timeslot.

Table 19 *Signal handler action return values*

9.6.5 Ending a timeslot in time

The application is responsible for keeping track of timing within the timeslot and ensuring that the application's use of the peripherals does not last for longer than the granted timeslot. For these purposes, the application is granted access to the TIMER0 peripheral for the length of the timeslot. This timer is started from zero by the SoftDevice at the start of the timeslot, and is configured to run at 1 MHz. The recommended practice is to set up a timer interrupt that expires before the timeslot expires, with enough time left of the timeslot to do any clean-up actions before the timeslot ends. Such a timer interrupt can also be used to request an extension of the timeslot, but there must still be enough time to clean up if the extension is not granted.

9.6.6 The signal handler runs at LowerStack priority

The signal handler runs at LowerStack priority, which is the highest priority. Therefore, it cannot be interrupted by any other activity. Also, as for the App(H) interrupt, SVC calls are not available in the signal handler. It is a requirement that processing in the signal handler does not exceed the granted time of the timeslot. If it does, the behavior of the SoftDevice is undefined and the SoftDevice may malfunction.

The signal handler may be called several times during a timeslot. It is recommended to use the signal handler only for the real time signal handling. When a signal has been handled, exit the signal handler to wait for the next signal. Processing other than signal handling should be run at lower priorities, outside of the signal handler.

9.7 Timeslot usage examples

In this section we provide several timeslot usage examples and describe the sequence of events within them.

9.7.1 Complete session example

Figure 7 shows a complete timeslot session. In this case, only timeslot requests from the application are being scheduled, there is no SoftDevice activity.

At start, the application calls the API to open a session and to request a first timeslot (which must be of type *earliest*). The SoftDevice schedules the timeslot. At the start of the timeslot, the SoftDevice calls the application signal hander with the START signal. After this, the application is in control and has access to the peripherals. The application will then typically set up TIMER0 to expire before the end of the timeslot, to get a signal that the timeslot is about to end. In the last signal in the timeslot, the application uses the signal handler return action to request a new timeslot 100 ms after the first.

The following timeslots (the middle timeslot in ***Figure 7***) are all similar. The signal handler is called with the START signal at the start of the timeslot. The application then has control, but must arrange for a signal to come towards the end of the timeslot. As the return value for the last signal in the timeslot, the signal handler requests a new timeslot using the REQUEST_AND_END action.

Eventually, the application does not require the radio any more. So, at the last signal in the last timeslot, the application returns END from the signal handler. The SoftDevice then sends an IDLE event to the application event handler. The application calls *session_close*, and the SoftDevice sends the CLOSED event. The session has now ended.

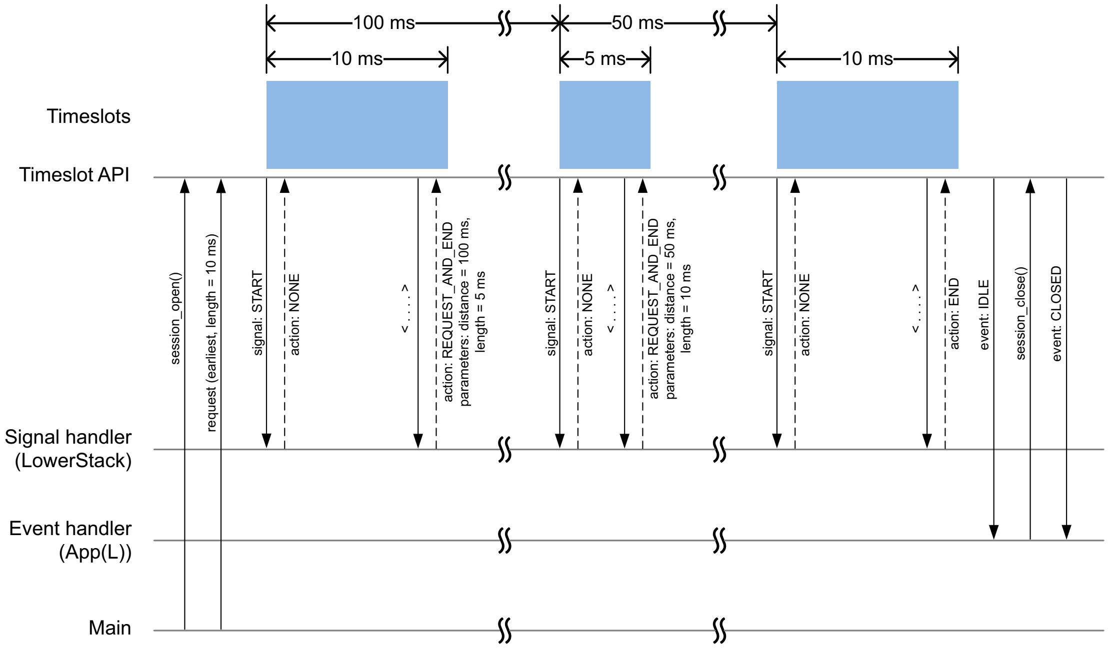


Figure 7 *Complete session example*

9.7.2 Blocked timeslot example

Figure 8 shows a situation in the middle of a session where a requested timeslot cannot be scheduled. At the end of the first timeslot in ***Figure 8***, the application signal handler returns a REQUEST_AND_END action to request a new timeslot. The new timeslot cannot be scheduled as requested, because of a collision with an already scheduled SoftDevice activity. The application is notified about this by a BLOCKED event to the application event handler. The application then makes a new request further out in time. This request succeeds (it does not collide with anything), and a new timeslot is scheduled.

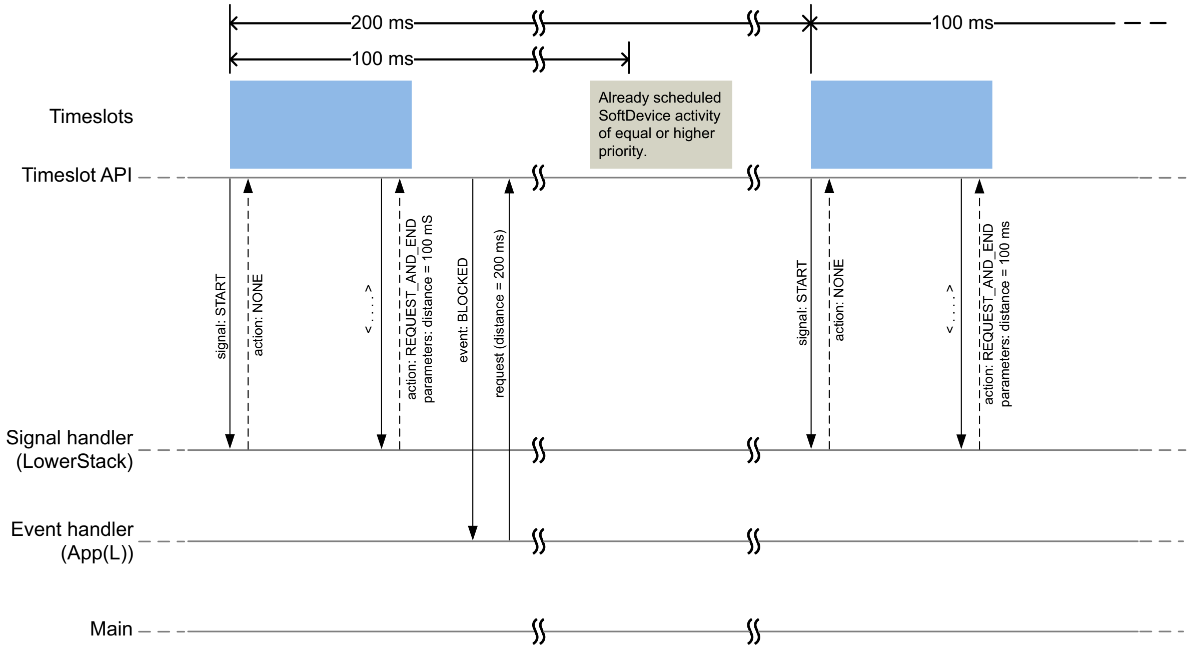


Figure 8 *Blocked timeslot example*

9.7.3 Canceled timeslot example

Figure 9 on page 28 shows a situation in the middle of a session where a requested and scheduled application timeslot is being revoked. The upper part of ***Figure 9*** on page 28 shows that the application has ended a timeslot by returning the REQUEST_AND_END action, and the new timeslot has been scheduled. The new scheduled timeslot has not been started yet, it is still some time into the future. The lower part of ***Figure 9*** on page 28 shows the situation some time later. In the meantime, time for a SoftDevice activity of higher priority has been requested internally in the SoftDevice, at a time which collides with the scheduled application timeslot. To accommodate the higher priority request, the application timeslot has been removed from the schedule, and the higher priority SoftDevice activity scheduled instead. The application is notified about this by a CANCELED event to the application event handler. The application then makes a new request further out in time. This request succeeds (it does not collide with anything), and a new timeslot is scheduled.

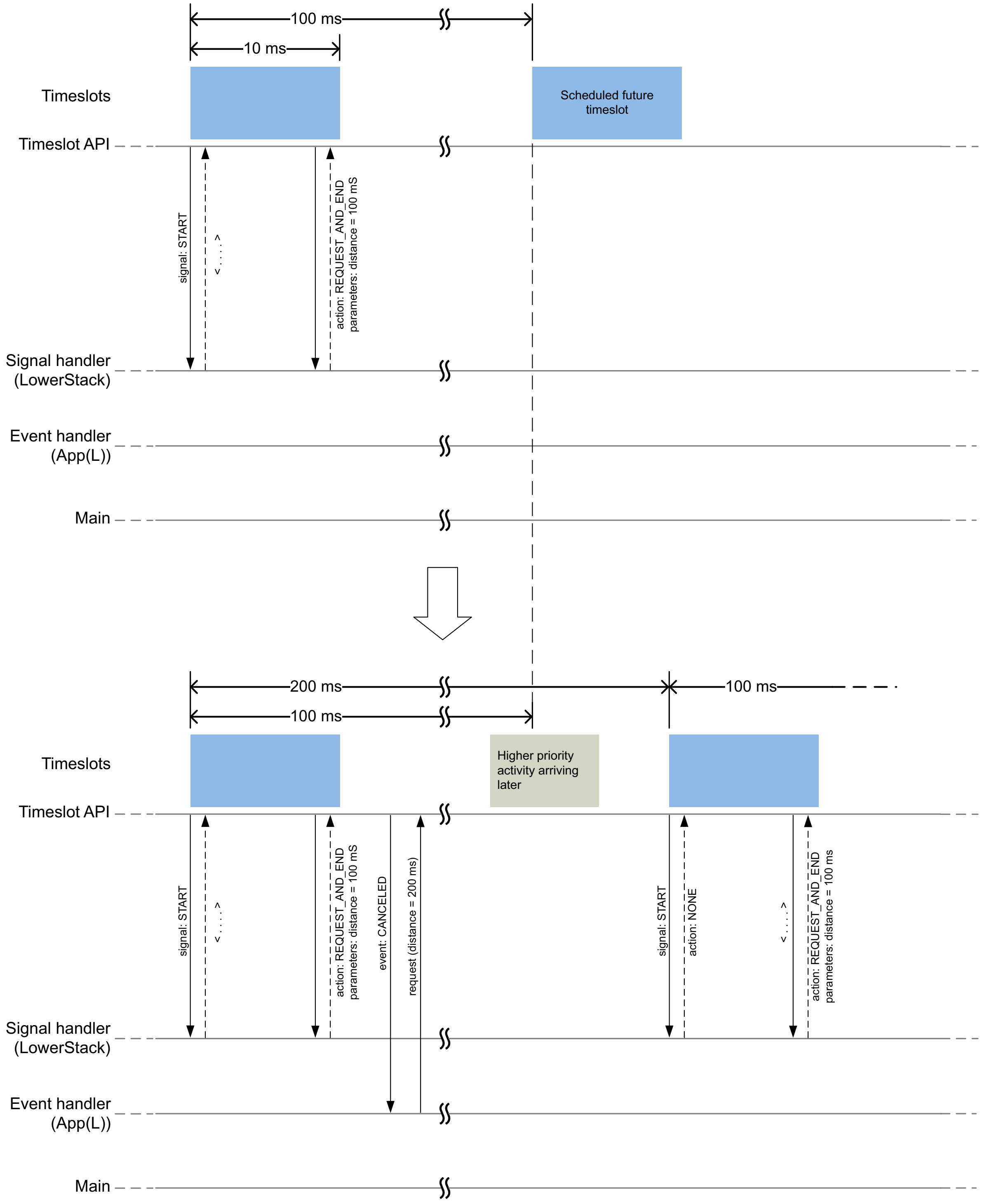


Figure 9 *Canceled timeslot example*

9.7.4 Timeslot extension example

Figure 10 shows how an application can use timeslot extension to create long continuous timeslots that will give the application as much radio time as possible while disturbing the SoftDevice activities as little as possible. In the first slot in ***Figure 10***, the application uses the signal handler return action to request an extension of the timeslot. The extension is granted, and the timeslot is seamlessly prolonged. The second attempt at extending the timeslot fails, as a further extension would cause a collision with a SoftDevice activity that has been scheduled. Therefore the application does a new request, of type *earliest*. This results in a new radio timeslot being scheduled immediately after the SoftDevice activity. This new timeslot can be extended a number of times.

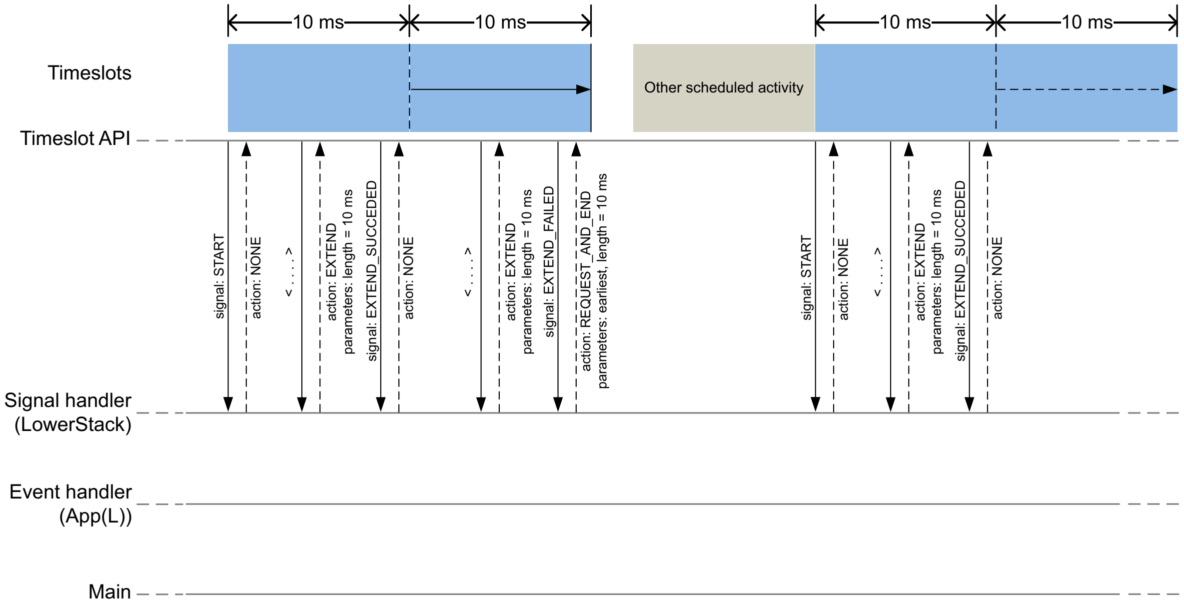


Figure 10 *Timeslot extension example*

10 Master Boot Record and Bootloader

The SoftDevice supports the use of a bootloader. A bootloader may be used to update the firmware on the chip. The SoftDevice also contains a Master Boot Record (MBR). The MBR is necessary in order for the bootloader to update the SoftDevice, or to update the bootloader itself. The MBR is a required component in the system. The inclusion of a bootloader is optional.

10.1 Master Boot Record

The Master Boot Record (MBR) module occupies a defined region in flash memory where the System Vector table resides. All exceptions (reset, hard fault, interrupts, SVC) are processed first by the MBR and then forwarded to appropriate handlers (for example bootloader or SoftDevice). The main feature of the MBR is to provide an interface to allow in-system updates of the SoftDevice and bootloader firmware. The MBR is not updated between versions of the SoftDevice, meaning that during an update process, the MBR is never erased. The MBR ensures safe restart of any ongoing update process if an unexpected reset occurs.

10.2 Bootloader

A bootloader may be used to handle in-system update procedures. The bootloader has access to the full SoftDevice API and can be implemented just as any application that uses a SoftDevice. In particular, the bootloader can make use of the SoftDevice API to enable protocol stack interaction.

The bootloader is supported in the SoftDevice architecture by using a configurable base address for the bootloader in application code space. The base address is configured by setting the UICR.BOOTLOADERADDR register. The bootloader is responsible for determining the start address of the application. It uses sd_softdevice_vector_table_base_set(uint32_t address) to tell the SoftDevice where the application starts. The bootloader is also responsible for keeping track of, and verifying the SoftDevice. If an unexpected reset occurs during an update of the SoftDevice, it is the responsibility of the bootloader to detect this and recover.

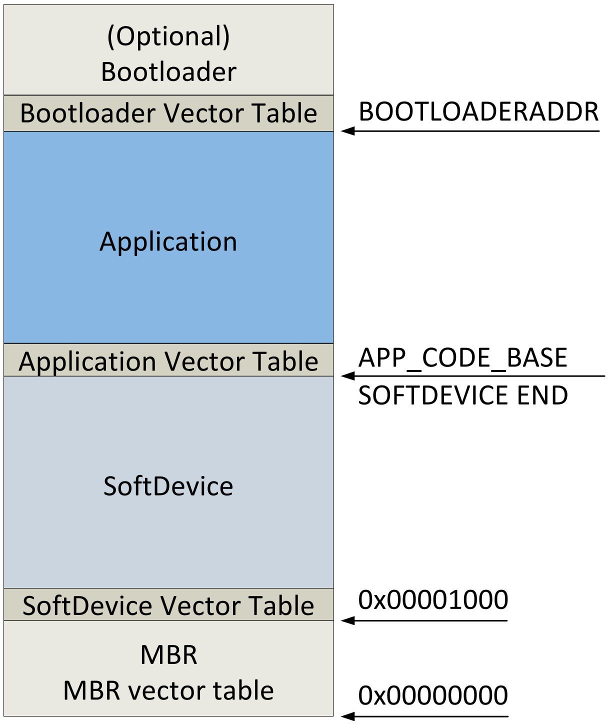


Figure 11 *MBR, SoftDevice, and bootloader architecture*

10.3 Master Boot Record (MBR) and SoftDevice reset behavior

Upon system reset, the MBR Reset Handler is run as specified by the System Vector table. The MBR and SoftDevice reset behavior is as follows:

- If an in-system bootloader update procedure is in progress:
  - Then in-system update procedure is run to completion.
  - System is reset.
- Else if SD_MBR_COMMAND_VECTOR_TABLE_BASE_SET has been called previously:
  - Forward interrupts to the parameter given.
  - Run from Reset Handler (defined in vector table at parameter given).
- Else if a bootloader is present:
  - Forward interrupts to the bootloader.
  - Run Bootloader Reset Handler (defined in bootloader vector table at BOOTLOADERADDR).
- Else if a SoftDevice is present:
  - Forward interrupts to SoftDevice.
  - Run SoftDevice Reset Handler (defined in SoftDevice vector table at 0x00001000).
  - In this case, APP_CODE_BASE is hardcoded inside the SoftDevice.
  - SoftDevice run Application Reset Handler (defined in application vector table at APP_CODE_BASE).
- Else system startup error:
  - Sleep forever.

10.4 Master Boot Record (MBR) and SoftDevice initialization

The SoftDevice can be enabled by the bootloader by performing the following in this order:

1. Issue command for MBR to forward interrupts to the SoftDevice using sd_mbr_command() with SD_MBR_COMMAND_INIT_SD.
2. Issue command for the SoftDevice to forward interrupts to the bootloader using sd_softdevice_vector_table_base_set(uint32_t address) with BOOTLOADERADDR as parameter.
3. Enable SoftDevice using sd_softdevice_enable().

For a bootloader to transfer execution from itself to the application, the following can be performed:

1. If interrupts have not been forwarded to SoftDevice, issue command for MBR to forward interrupts to SoftDevice using sd_mbr_command() with SD_MBR_COMMAND_INIT_SD.
2. Ensure SoftDevice is disabled using sd_softdevice_disable().
3. Issue command for the SoftDevice to forward interrupts to the application using sd_softdevice_vector_table_base_set(uint32_t address) with APP_CODE_BASE as parameter.
4. Branch to application's reset handler after reading the handler from the Application Vector Table.

11 SoC resource requirements

The SoftDevice and MBR are designed to be installed on a System on Chip (SoC) in the lower part of the code memory space. After a reset, the MBR will use some RAM to store state information. When the SoftDevice is enabled, it uses resources on the chip including RAM and hardware peripherals like the radio. This chapter describes how the MBR and SoftDevice uses resources. The SoftDevice requirements are shown both when enabled and disabled.

11.1 Attribute Table size

The size of the Attribute Table can be configured through the SoftDevice API when initializing the *Bluetooth* low energy stack. The amount of RAM reserved by the SoftDevice, and thereby the amount of RAM available for the application, is dependent upon this configuration.

The Attribute Table size (ATTR_TAB_SIZE) has a default value of 0x700 bytes. This value has been chosen for compatibility with previous SoftDevice versions where the Attribute Table size was not configurable, and using this default value will result in the same SoftDevice RAM requirements as for those previous versions.

Applications that require an Attribute Table smaller or bigger than the default one can choose to either reduce or increase the Attribute table size. The amount of RAM reserved by the SoftDevice, and the start address for the application RAM (APP_RAM_BASE) will then change accordingly. The application linker configuration must be adapted to reflect the changed SoftDevice RAM requirement.

Refer to the SoftDevice API for more information on how to configure the Attribute Table size.

11.2 Memory resource map and usage

The memory map for program memory and RAM at run time with the SoftDevice enabled is illustrated in ***Figure 12*** below. Memory resource requirements, both when the SoftDevice is enabled and disabled, are shown in ***Table 20*** on page 35. Note the definitions of Region 0 (R0) and Region 1 (R1) are valid only when the CLENR0 and RLENR0 registers are optionally programmed to enable memory protection. See the MPU chapter in the *nRF51 Reference Manual* for more details.

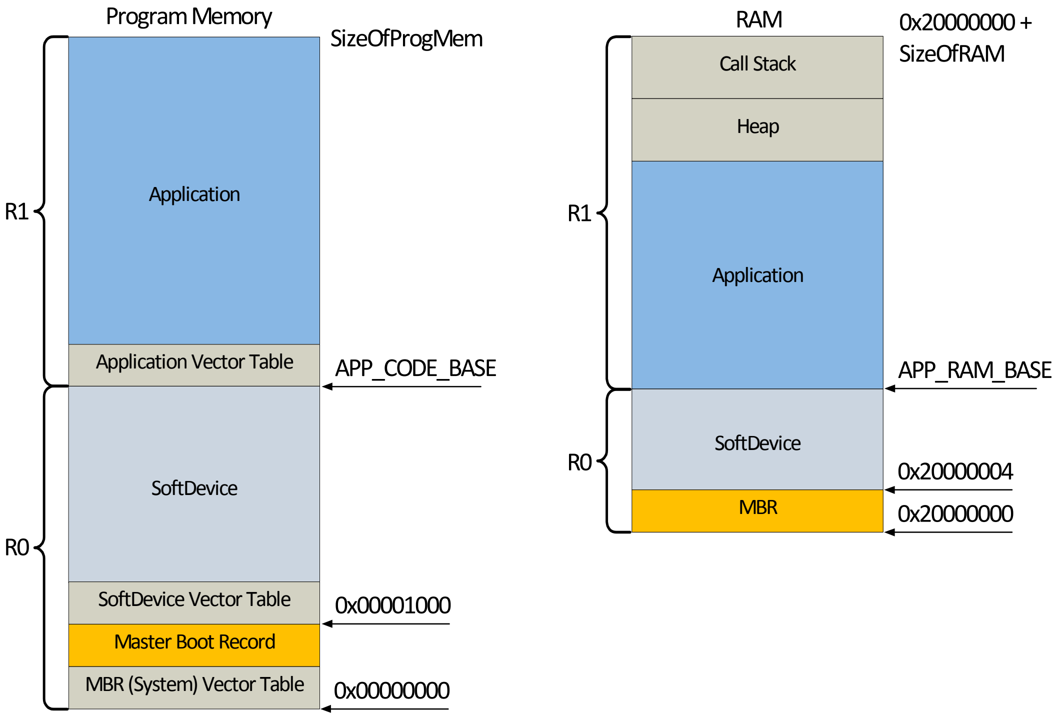


Figure 12 *Memory resource map*

Flash	S110 Enabled	S110 Disabled
SoftDevice	92 kB[1]	92 kB
MBR	4 kB	4 kB
APP_CODE_BASE	0x00018000	0x00018000

RAM	S110 Enabled	S110 Disabled
SoftDevice	0x1900 - 4 + ATTR_TAB_SIZE[2] **Default:** 8188 (0x1900 - 4 + 0x700) **Minimum:** 6612 (0x1900 - 4 + 216)	4 bytes
MBR	4 bytes	4 bytes
APP_RAM_BASE	0x20001900 + ATTR_TAB_SIZE[2] **Default:** 0x20002000 (0x2001900 + 0x700) **Minimum:** 0x200019D8 (0x2001900 + 0xD8)	0x20000008

Call stack[3]	S110 Enabled	S110 Disabled
Maximum usage	1536 bytes (0x600)	0 kB

Heap	S110 Enabled	S110 Disabled
Maximum allocated bytes	0 bytes	0 bytes

1. 1 kB = 1024 bytes.
2. See ***Section 11.1 "Attribute Table size"*** on page 33.
3. This is only the call stack used by the SoftDevice at run time. The application call stack memory usage must be added for the total call stack size to be set in the user application.

Table 20 *S110 Memory resource requirements*

11.3 Hardware blocks and interrupt vectors

Table 21 defines access types used to indicate the availability of hardware blocks to the application. ***Table 22*** on page 36 specifies the access the application has, per hardware block, both when the SoftDevice is enabled and disabled.

Access	Definition
Restricted	Used by the SoftDevice and outside the application sandbox. Application has limited access through the SoftDevice API.
Blocked	Used by the SoftDevice and outside the application sandbox. Application has no access.
Open	Not used by the SoftDevice. Application has full access.

Table 21 *Hardware access type definitions*

ID	Base address	Instance	Access (SoftDevice enabled)	Access (SoftDevice disabled)
0	0x40000000	MPU	Restricted	Open
0	0x40000000	POWER	Restricted	Open
0	0x40000000	CLOCK	Restricted	Open
1	0x40001000	RADIO	Blocked[1]	Open
2	0x40002000	UART0	Open	Open
3	0x40003000	SPI0/TWI0	Open	Open
4	0x40004000	SPI1/TWI1/SPIS1	Open	Open
...				
6	0x40006000	GPIOTE	Open	Open
7	0x40007000	ADC	Open	Open
8	0x40008000	TIMER0	Blocked[1]	Open
9	0x40009000	TIMER1	Open	Open
10	0x4000A000	TIMER2	Open	Open
11	0x4000B000	RTC0	Blocked	Open
12	0x4000C000	TEMP	Restricted	Open
13	0x4000D000	RNG	Restricted	Open
14	0x4000E000	ECB	Restricted	Open
15	0x4000F000	CCM	Blocked[1]	Open
15	0x4000F000	AAR	Blocked[1]	Open
16	0x40010000	WDT	Open	Open
17	0x40011000	RTC1	Open	Open
18	0x40012000	QDEC	Open	Open
19	00x4001300	LCOMP	Open	Open
20	0x40014000	Software interrupt	Open	Open
21	0x40015000	Radio Notification	Restricted[2]	Open
22	0x40016000	SoC Events	Blocked	Open
23	0x40017000	Software interrupt	Blocked	Open
24	0x40018000	Software interrupt	Blocked	Open
25	0x40019000	Software interrupt	Blocked	Open
...				
30	0x4001E000	NVMC	Restricted	Open
31	0x4001F000	PPI	Open[3]	Open
NA	0x50000000	GPIO P0	Open	Open
NA	0xE000E100	NVIC	Restricted[4]	Open

1. Available to the application in Multiprotocol Timeslot API timeslots, see ***Chapter 9 "Concurrent Multiprotocol Timeslot API"*** on page 20.
2. Blocked only when radio notification signal is enabled. See ***Table 23*** on page 37 for software interrupt allocation.
3. See ***Section 11.5 "Programmable Peripheral Interconnect (PPI)"*** on page 37 for limitations on the use of PPI when the SoftDevice is enabled.
4. Not protected. For robust system function, the application program must comply with the restriction and use the NVIC API for configuration when the SoftDevice is enabled.

Table 22 *Peripheral protection and usage by SoftDevice*

11.4 Application signals - software interrupts

Software interrupts are used by the SoftDevice to signal a change in events. ***Table 23*** shows the allocation of software interrupt vectors to SoftDevice signals.

Software interrupt (SWI)	Peripheral ID	SoftDevice Signal
0	20	Unused by the SoftDevice and available to the application.
1	21	Radio Notification - optionally configured through API.
2	22	SoftDevice Event Notification.
3	23	Reserved.
4	24	LowerStack processing - not user configurable.
5	25	UpperStack signaling - not user configurable.

Table 23 *Software interrupt allocation*

11.5 Programmable Peripheral Interconnect (PPI)

PPI may be configured using the PPI API in the SoC library. This API is available both when the SoftDevice is disabled and when it is enabled. It is also possible to configure the PPI using the CMSIS directly.

When the SoftDevice is disabled, all PPI channels and groups are available to the application. When the SoftDevice is enabled, some PPI channels and groups are in use by the SoftDevice. See ***Table 24***.

When the SoftDevice is enabled, the application program must not change the configuration of PPI channels or groups used by the SoftDevice. Failing to comply with this will cause the SoftDevice to not operate properly.

PPI channel allocation	SoftDevice enabled	SoftDevice disabled
Application	Channels 0 - 13	Channels 0 - 15
SoftDevice	Channels 14 - 15[1]	-

Preprogrammed channels	SoftDevice enabled	SoftDevice disabled
Application	-	Channels 20 - 31
SoftDevice	Channels 20 - 31	-

PPI group allocation	SoftDevice enabled	SoftDevice disabled
Application	Groups 0 - 1	Groups 0 - 3
SoftDevice	Groups 2 - 3	-

[1] Available to the application in Multiprotocol Timeslot API timeslots, see ***Chapter 9 "Concurrent Multiprotocol Timeslot API"*** on page 20.

Table 24 *PPI channel and group availability*

11.6 SVC number ranges

Table 25 shows which SVC numbers an application program can use and which numbers are used by the SoftDevice.

Note: The SVC number allocation does not change with the state of the SoftDevice (enabled or disabled).

SVC number allocation	SoftDevice enabled	SoftDevice disabled
Application	0x00-0x0F	0x00-0x0F
SoftDevice	0x10-0xFF	0x10-0xFF

Table 25 *SVC number allocation*

11.7 External requirements

For correct operation of the SoftDevice, it is a requirement that the 16 MHz crystal oscillator (16 MHz XOSC) startup time is less than 1.5 ms. The external clock crystal and other related components must be chosen accordingly. Data for the device XOSC input can be found in the product specification for the device.

12 Processor availability and interrupt latency

This chapter documents key SoftDevice performance parameters for processor availability and interrupt latency.

12.1 Interrupt latency due to SoC framework

Latency, additional to ARM® Cortex™-M0 hardware architecture latency, is introduced by SoftDevice logic to manage interrupt events. This latency occurs when an interrupt is forwarded to the application from the SoftDevice and is part of the minimum latency for each application interrupt. Additional latency is incurred due to interrupt processing and forwarding performed by the Master Boot Record (MBR). The maximum application interrupt latency is dependent on protocol stack activity as described in ***Section 12.2 "Processor availability"*** on page 40.

Interrupt	CPU cycles	Latency at 16 MHz
Open peripheral interrupt	49	3.1 µs
Blocked or restricted peripheral interrupt (only forwarded when SoftDevice disabled)	67	4.2 µs
Application SVC interrupt	43	2.7 µs

Table 26 *Additional latency due to SoftDevice and MBR processing*

See ***Table 22*** on page 36 for open, blocked, and restricted peripherals.

12.2 Processor availability

Appendix A on page 50 describes interrupt management in SoftDevices and is required knowledge for understanding this section.

The SoftDevice protocol stack runs in the LowerStack and UpperStack interrupts. These protocol stack interrupts determine the processor availability and latencies for the interrupts/priorities available to the application - App(H), App(L), and main.

LowerStack processing will determine the processor availability and interrupt latency for App(H) (and all lower priorities), while LowerStack, App(H), and UpperStack processing together will determine the processor availability for App(L) and main context. ***Figure 13*** illustrates UpperStack activity (API calls) and LowerStack activity (Protocol events) and the time reserved/not reserved for those interrupts.

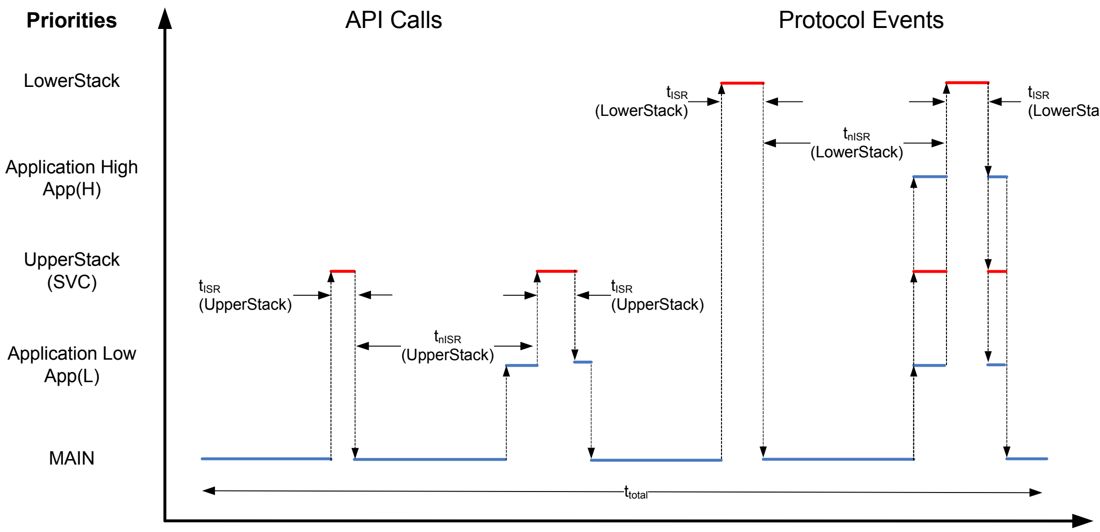


Figure 13 *UpperStack and LowerStack activity*

Table 27 describes the terms used for interrupt latency timings.

Parameter	Description
t_{ISR} (LowerStack)	Interrupt processing time in LowerStack. This is the interrupt latency for App(H) (and lower priorities).
t_{nISR} (LowerStack)	Time between LowerStack interrupts. This is the time available to run for App(H) (and lower priorities).
t_{ISR} (UpperStack)	Interrupt processing time in UpperStack. This is the interrupt latency for App(L) and processing latency for main context.
t_{nISR} (UpperStack)	Time between UpperStack interrupts. This is the time available to run for App(L) and main context.

Table 27 *SoftDevice interrupt latency definitions*

12.3 BLE peripheral performance

This section describes the processor availability and interrupt latency for the BLE peripheral stack.

The interrupt latency and processor availability interrupt latencies are dependent upon whether the SoftDevice uses CPU suspend[1] during radio activity or not. For S110 SoftDevices 7.0 and earlier, CPU suspend was always used. For version 7.1, CPU Suspend was enabled by default, but could be turned off. For current S110 SoftDevice versions (S110 8.x), CPU suspend is by default not enabled, but may optionally be enabled for compatibility with older versions of nRF51 chips. See your S110 SoftDevice release documentation for details. This document describes interrupt latency and CPU availability when CPU Suspend is not used.

12.3.1 Advertising interrupt latency

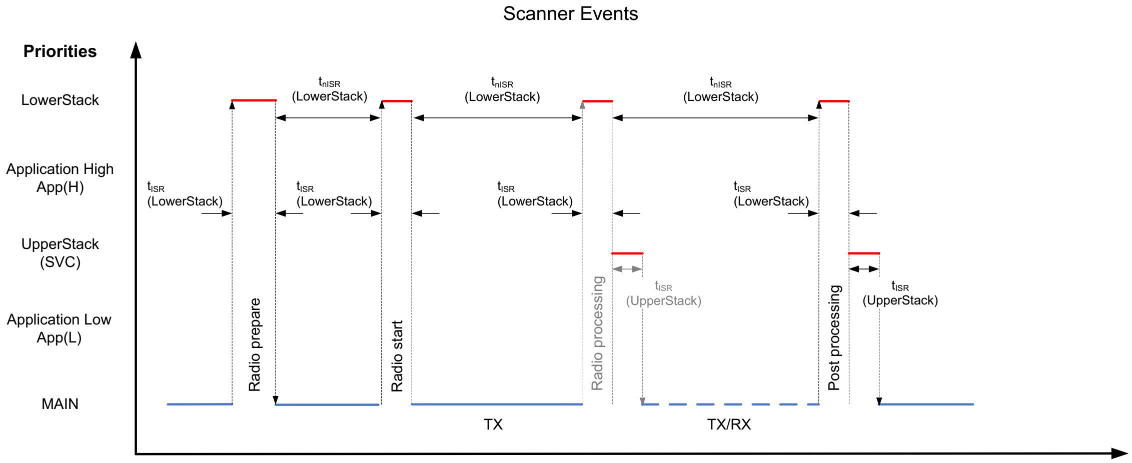


Figure 14 *Advertising*

For advertising, the pattern of LowerStack activity is as follows:

There is first Radio prepare, followed by Radio start, which starts the actual advertising. Depending upon the type of advertising, this may be followed by one or more instances of Radio processing (including UpperStack processing) and further reception/transmission. Finally, advertising ends with Post processing and some UpperStack activity.

Parameter	Description	Min.	Typ.	Max.
$t_{\text{ISR(LowerStack),RadioPrepare}}$	Interrupt latency preparing the radio for advertising.			120 µs
$t_{\text{ISR(LowerStack),RadioStart}}$	Interrupt latency starting the advertising.			50 µs
$t_{\text{ISR(LowerStack),RadioProcessing}}$	Processing after sending/receiving packet.			220 µs
$t_{\text{ISR(LowerStack),PostProcessing}}$	Interrupt latency at the end of an advertising event.			440 µs
$t_{\text{nISR(LowerStack)}}$	Distance between interrupts during advertising.	40 µs	150 µs	
$t_{\text{ISR(UpperStack)}}$	UpperStack interrupt at the end of a advertising event.			0.1 ms

Table 28 *Interrupt latency for advertising*

---

[1] CPU Suspend: During BLE protocol events, LowerStack interrupts are extended by a CPU Suspend state during radio activity to improve link integrity. This means LowerStack interrupts will block application and UpperStack processing during a Radio Activity for a time proportional to the number of packets transferred during the Radio activity period.

12.3.2 BLE peripheral connection

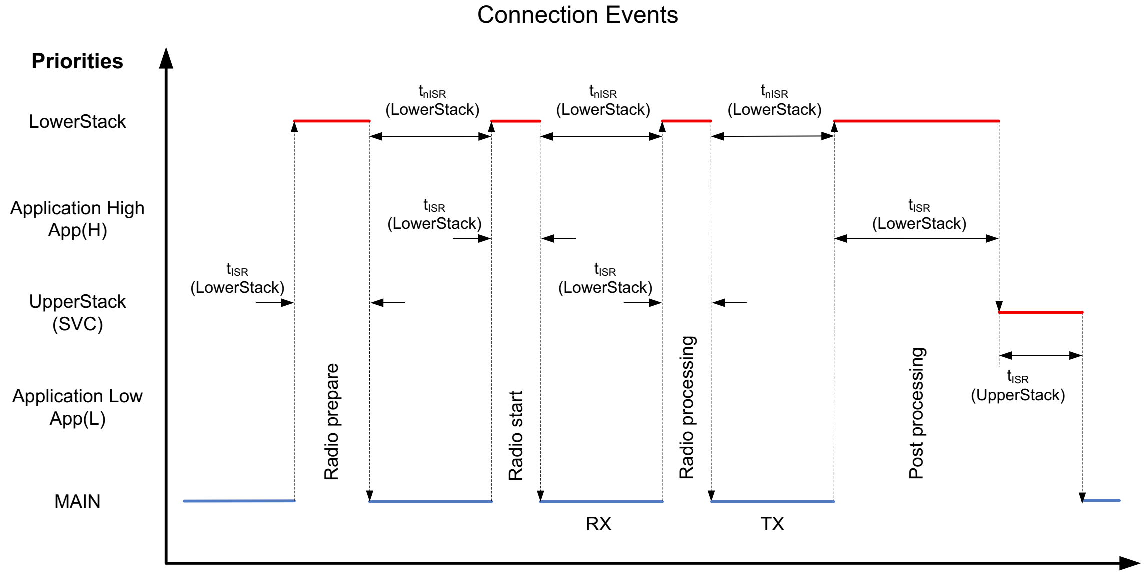


Figure 15 *Connection events*

In a connection event, the LowerStack activity is typically as follows: First there is Radio prepare and then Radio start, which starts the actual connection event (reception). When the reception is finished, there is a Radio processing including a switch to transmission. When the transmission is finished, there is either a Radio processing including a switch back to reception and possibly a new transmission after that, or the event ends with Post processing.

After the LowerStack Post processing, the UpperStack processes any received packets with data, executes GATT, ATT or SMP operations and generates events to the application as required. The UpperStack interrupt is therefore highly variable based on the stack operations executed.

The data in ***Table 29*** is for a connection under good conditions. Continued packet loss, clock drift, and other effects may force longer Radio activity and longer LowerStack processing. This may affect the CPU availability and interrupt latency for lower priorities.

Parameter	**Description**	**Min.**	**Typ.**	**Max.**
$t_{ISR(LowerStack),RadioPrepare}$	Interrupt latency preparing the radio for connection event.			150 µs
$t_{ISR(LowerStack),RadioStart}$	Interrupt latency starting the connection event.			40 µs
$t_{ISR(LowerStack),RadioProcessing}$	Interrupt latency after sending packet.			290 µs
$t_{ISR(LowerStack),PostProcessing}$	Interrupt latency at the end of an connection event.			510 µs
$t_{nISR(LowerStack)}$	Distance between connection event interrupts.	30 µs		1400 µs
$t_{ISR(UpperStack)}$	UpperStack interrupt processing.			1.1 ms

Table 29 *Interrupt latency when connected*

12.3.3 API calls

The following table describes the timing for API call handling in the UpperStack.

Parameter	Description	UpperStack		
		Min	Nom	Max
$t_{ISR(upper\ stack)}$	Maximum interrupt processing time	-	-	250 µs
$t_{nISR(upper\ stack)}$	Minimum time between interrupts	Application dependent.[1]		

1. Calls to the SoftDevice API trigger the upper stack interrupt.

Table 30 SoftDevice interrupt latency - UpperStack

12.3.4 CPU utilization in connection

Table 31 shows the CPU capacity available for an application with given a set of typical stack connection parameters.

BLE connection configuration	% CPU capacity available
Connection interval 100 ms No data transfer	~99%
Connection interval 100 ms 1 packet transfer per event (bidirectional)	~97%
Connection interval 7.5 ms 4 packet transfer per event	15%

Table 31 CPU capacity available for the application, for some connection configurationss

12.4 Performance with Flash memory API and Concurrent Multiprotocol Timeslot API

The LowerStack interrupt is also used by the Flash memory API processing and by the Concurrent Multiprotocol Timeslot API processing. Therefore use of these APIs may affect CPU availability and interrupt latencies for all lower priorities. The effects of this are dependent upon the application and the use case.

13 BLE data throughput

The maximum data throughput limits in ***Table 32*** apply to encrypted packet transfers. To achieve maximum data throughput, the application must exchange data at a rate that matches on-air packet transmissions and use the maximum data payload per packet.

Protocol	Role	Method	Maximum data throughput
L2CAP		Receive	140 kbps
		Send	140 kbps
		Simultaneous send and receive	90 kbps (each direction)
GATT	Client	Receive Notification	125 kbps
		Send Write command	125 kbps
		Send Write request	10 kbps
		Simultaneous receive Notification and send Write command	100 kbps (each direction)
GATT	Server	Send Notification	125 kbps
		Receive Write command	125 kbps
		Receive Write request	10 kbps
		Simultaneous send Notification and receive Write command	100 kbps (each direction)

Table 32 *L2CAP and GATT maximum data throughput*

Note: 1 kbps = 1000 bits per second

14 BLE power profiles

This chapter provides power profiles for MCU activity during *Bluetooth* low energy Radio Events implemented in the SoftDevice. These profiles give a detailed overview of the stages of a Radio Event, the approximate timing of stages within the event, and how to calculate the peak current at each stage using data from the product specification. The LowerStack CPU profile during the event is shown separately. These profiles are based on typical events with empty packets.

14.1 Connection event

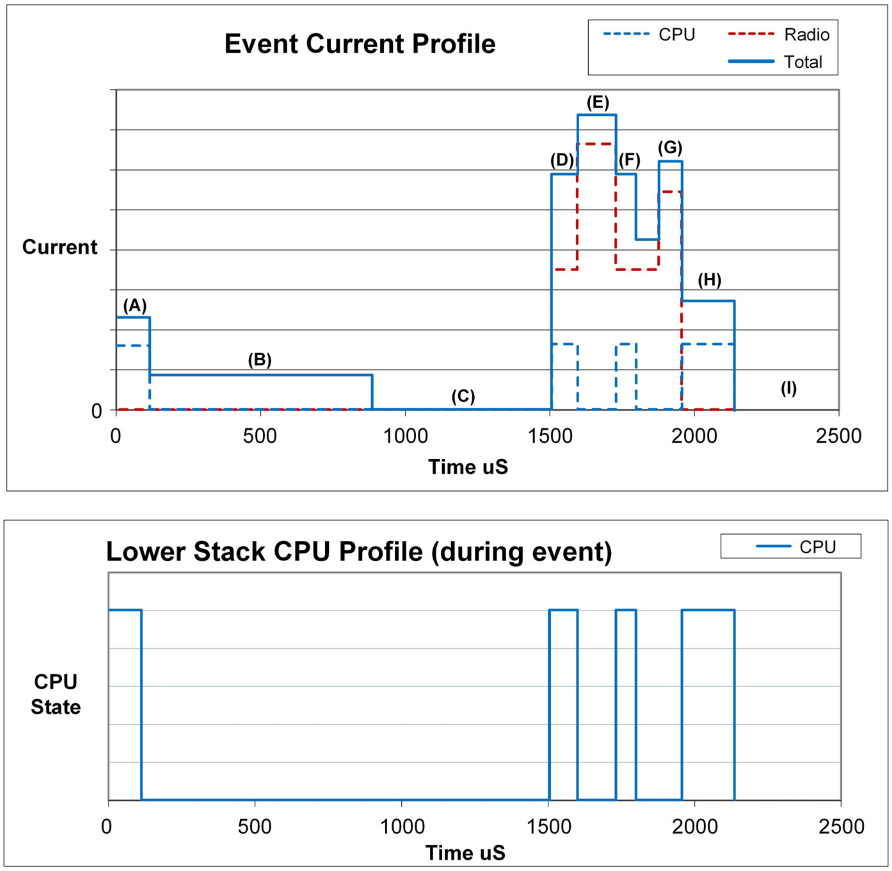


Figure 16 *Connection event*

Stage	Description	Current Calculations[1]
(A)	Preprocessing	$I_{ON} + I_{RTC} + I_{X32k} + I_{CPU,Flash} + I_{START,X16M}$
(B)	Standby + XO ramp	$I_{ON} + I_{RTC} + I_{X32k} + I_{START,X16M}$
(C)	Standby	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M}$
(D)	Radio Start	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M} + \int(I_{START,RX}) + I_{CPU,Flash}$
(E)	Radio RX	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M} + I_{RX} + I_{CRYPTO}$
(F)	Radio turn-around	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M} + \int(I_{START,TX}) + I_{CPU,Flash}$
(G)	Radio TX	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M} + I_{TX,0dBM} + I_{CRYPTO}$
(H)	Post-processing	$I_{ON} + I_{RTC} + I_{X32k} + I_{CPU,Flash}$
(I)	Idle - connected	$I_{ON} + I_{RTC} + I_{X32k}$

[1] See the corresponding product specification for the symbol values.

Table 33 Connection event

Note: When using the 32.768 kHz RC oscillator, I_{RC32k} must be used instead of I_{X32k}.

14.2 Advertising event

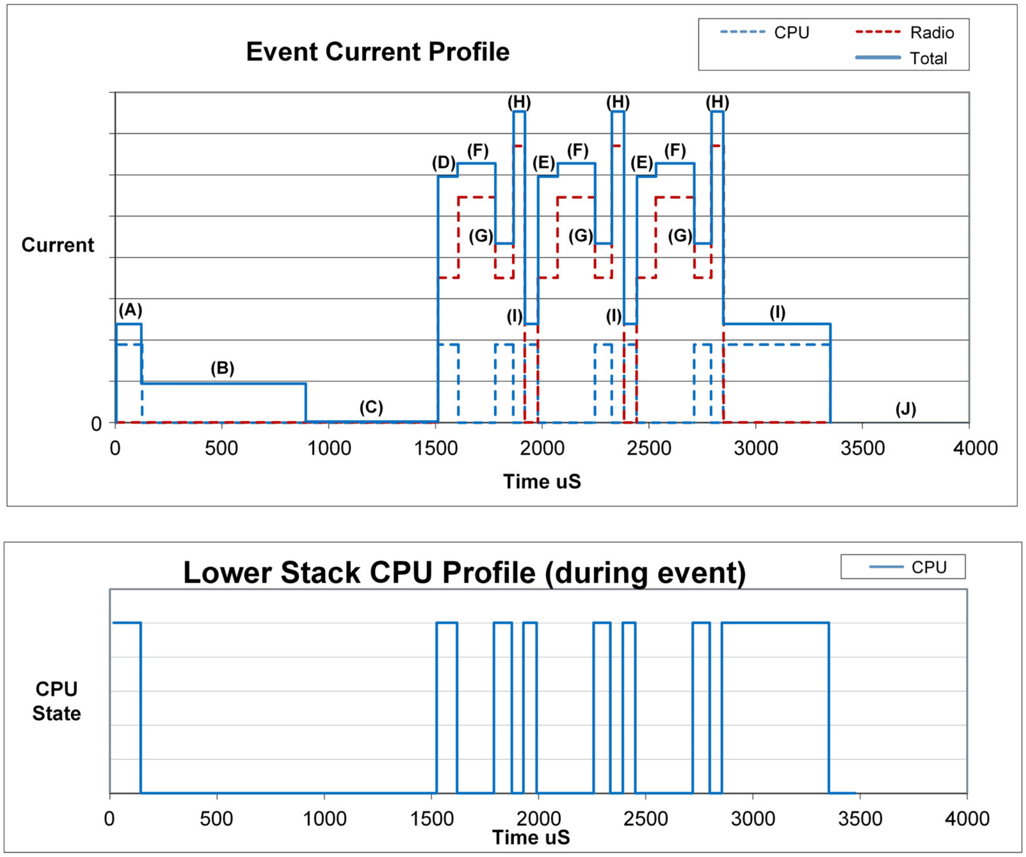


Figure 17 *Advertising event*

Stage	Description	Current Calculation[1]
(A)	Pre-processing	$I_{ON} + I_{RTC} + I_{X32k} + I_{CPU,Flash} + I_{START,X16M}$
(B)	Standby + XO ramp	$I_{ON} + I_{RTC} + I_{X32k} + I_{START,X16M}$
(C)	Standby	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M}$
(D)	Radio start/switch	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M} + \int (I_{START,TX}) + I_{CPU,Flash}$
(E)	Radio start	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M} + \int (I_{START,TX})$
(F)	Radio TX	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M} + I_{TX,0dBM}$
(G)	Radio turn-around	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M} + \int (I_{START,RX}) + I_{CPU,Flash}$
(H)	Radio RX	$I_{ON} + I_{RTC} + I_{X32k} + I_{X16M} + I_{RX}$
(I)	Post-processing	$I_{ON} + I_{RTC} + I_{X32k} + I_{CPU,Flash}$
(J)	Idle	$I_{ON} + I_{RTC} + I_{X32k}$

1. See the corresponding product specification for the symbol values.

Table 34 Advertising event

Note: When using the 32.768 kHz RC oscillator, I_{RC32k} must be used instead of I_{X32k}.

15 SoftDevice identification and revision scheme

The SoftDevices will be identified by the SoftDevice part code, a chip series identifier or qualified chip part code (for example nRF51 or nRF51822), and a version string.

For revisions of the SoftDevice that are production qualified, the version string consists of major, minor, and revision numbers only, as described in ***Table 35***.

For revisions of the SoftDevice that are not production qualified, a build number and a test qualification level (alpha/beta) are appended to the version string.

For example: s110_nrf51822_1.2.3-4.alpha, where major = 1, minor = 2, revision = 3, build number = 4 and test qualification level is alpha. Additional SoftDevice revision examples are given in ***Table 36***.

Revision	Description
Major increments	Modifications to the API or the function or behavior of the implementation or part of it have changed. Changes as per Minor Increment may have been made. Application code will not be compatible without some modification.
Minor increments	Additional features and/or API calls are available. Changes as per Revision Increment may have been made. Application code may have to be modified to take advantage of new features.
Revision increments	Issues have been resolved or improvements to performance implemented. Existing application code will not require any modification.
Build number increment (if present)	New build of non-production version.

Table 35 *Revision scheme*

Sequence number	Description
s110_nrf51822_1.2.3-1.alpha	Revision 1.2.3, first build, qualified at alpha level
s110_nrf51822_1.2.3-2.alpha	Revision 1.2.3, second build, qualified at alpha level
s110_nrf51822_1.2.3-5.beta	Revision 1.2.3, fifth build, qualified at beta level
s110_nrf51822_1.2.3	Revision 1.2.3, qualified at production level

Table 36 *SoftDevice revision examples*

The test qualification levels are outlined in ***Table 37.***

Qualification	Description
Alpha	Development release suitable for prototype application development. Hardware integration testing is not complete. Known issues may not be fixed between alpha releases. Incomplete and subject to change.
Beta	Development release suitable for application development. In addition to alpha qualification: Hardware integration testing is complete. Stable, but may not be feature complete and may contain known issues. Protocol implementations are tested for conformance and interoperability.
Production	Qualified release suitable for product integration. In addition to beta qualification: Hardware integration tested over supported range of operating conditions. Stable and complete with no known issues. Protocol implementations conform to standards.

Table 37 *Test qualification levels*

15.1 MBR distribution and revision scheme

The MBR is distributed in each SoftDevice hex file. The version of the MBR distributed with the SoftDevice will be published in the release notes for the SoftDevice and uses the same major, minor and revision numbering scheme as described here.

15.2 Notification of SoftDevice revision updates

When new versions of a SoftDevice become available or the qualification status of a given revision of a SoftDevice is changed, product update notifications will be automatically forwarded, by email, to all users who have a profile configured to receive notifications from the Nordic Semiconductor website.

The SoftDevice will be updated with additional features and/or fixed issues if needed. Supported production versions of the SoftDevice will remain available after updates, so products do not need requalification on release of updates if the previous version is sufficiently feature complete for your product.

Appendix A SoftDevice architecture

Figure 1 is a block diagram of the nRF51 series software architecture including the standard ARM® CMSIS interface for nRF51 hardware, profile and application code, application specific peripheral drivers, and a firmware module identified as a SoftDevice.

A SoftDevice is precompiled and linked binary software implementing a wireless protocol. While it is software, application developers have minimal compile-time dependence on its features. The unique hardware and software supported framework, in which it executes, provides run-time isolation and determinism in its behavior. These characteristics make the interface comparable to a hardware peripheral abstraction with a functional, programmatic interface.

The SoftDevice Application Program Interface (API) is available to applications as a high-level programming language interface, for example, a C header file.

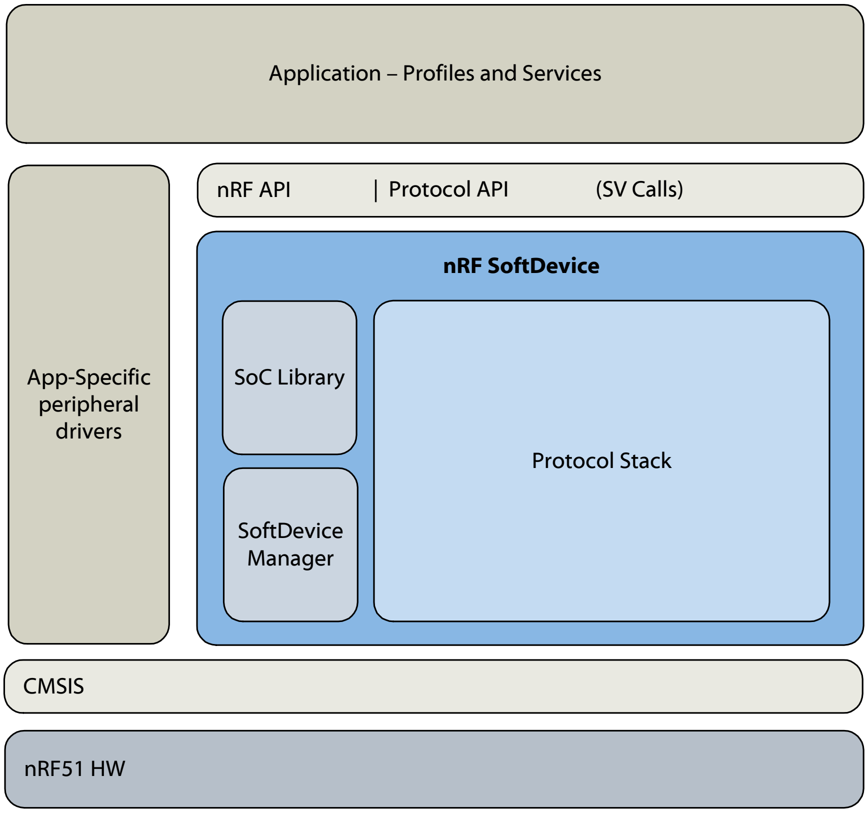


Figure 1 *Software architecture block diagram*

A SoftDevice consists of three main components:

1. SoC Library - API for shared hardware resource management (application coexistence).
2. SoftDevice manager - SoftDevice management API (enabling/disabling the SoftDevice, etc.).
3. Protocol stack - Implementation of protocol stack and API.

When the SoftDevice is disabled, only the SoftDevice Manager API is available for the application. For more information about enabling/disabling the SoftDevice, see the Softdevice enable and disable section on page 58.

SoC library

The SoC library provides functions for accessing shared hardware resources. The features of this library will vary between implementations of SoftDevices so detailed descriptions of the SoC library API are made available with the Software Development Kits (SDK) specific to each SoftDevice. The following is a summary of common components in the library.

Component	Description
NVIC	Wrapper functions for the CMSIS NVIC functions provided by ARM®. **Note:** To ensure reliable usage of the SoftDevice you must use the wrapper functions when the SoftDevice is enabled.
MUTEX	Disabling interrupts shall not be done while the SoftDevice is enabled. Mutex functions have been implemented to provide safe regions.
RAND	Random number generator - hardware sharing between SoftDevice and application.
POWER	Power management - Functions for power management.
CLOCK	Clock management – Functions for managing clock sources.
PPI	Safe PPI access to dedicated Application PPI channels.
PWR_MNG	Power management support (not a full implementation) for the application.

SoftDevice Manager

The SoftDevice Manager (SDM) API implements functions for controlling the state of the SoftDevice enabled/disabled. When enabled, the SDM configures low frequency clock (LFCLK) source, interrupt management and the embedded protocol stack.

Detailed documentation of the SDM API is made available with the Software Development Kits (SDK) specific to each SoftDevice.

Protocol stack

The major component in each SoftDevice is a wireless protocol stack providing abstract control of the RF transceiver features for wireless applications. For example, fully qualified *Bluetooth* low energy and ANT™ protocols layers may be implemented in a SoftDevice to provide application developers with an out-of-the-box solution for applications using standard 2.4 GHz protocols.

Application Program Interface (API)

In addition, to a Protocol API enabling wireless applications, there is a nRF API that supports both the SoftDevice manager and the SoC library. The nRF API is consistent across SoftDevices in the nRF51 range of ANT™ and *Bluetooth* products for code compatibility.

The SoftDevice API is implemented using thread-safe Supervisor Calls (SVC). All application interaction with the stack and libraries is asynchronous and event driven. From the application this looks like regular functions, but no compiling or linking is required. All SVC interface functions will be provided through header files for the SDM, SoC Library, and protocol(s).

SV calls are conceptually software triggered interrupts with a procedure call standard for parameter passing and return values. Each API call generates an interrupt allowing single-thread API context and SoftDevice function locations to be independent from the application perspective at compile-time. SoftDevice API functions can only be called from lower interrupt priority when compared to the SVC priority. See the Exception (interrupt) management with a SoftDevice section ***on page 54***.

Memory isolation and run-time protection

SoftDevice program memory, data memory and peripherals can be sandboxed[1] to prevent SoftDevice program corruption by the application ensuring robust and predictable performance. Sandboxing is enabled by writing the start address of the application program memory to UICR.CLENR0.

Program memory and RAM are divided into two regions using registers. Region 0 is occupied by the SoftDevice while Region 1 is available to the application.

Code regions are defined when programming a SoftDevice by setting a register defining program code length. RAM regions are defined at run-time when the SoftDevice is enabled. See ***Figure 2*** for an overview of regions.

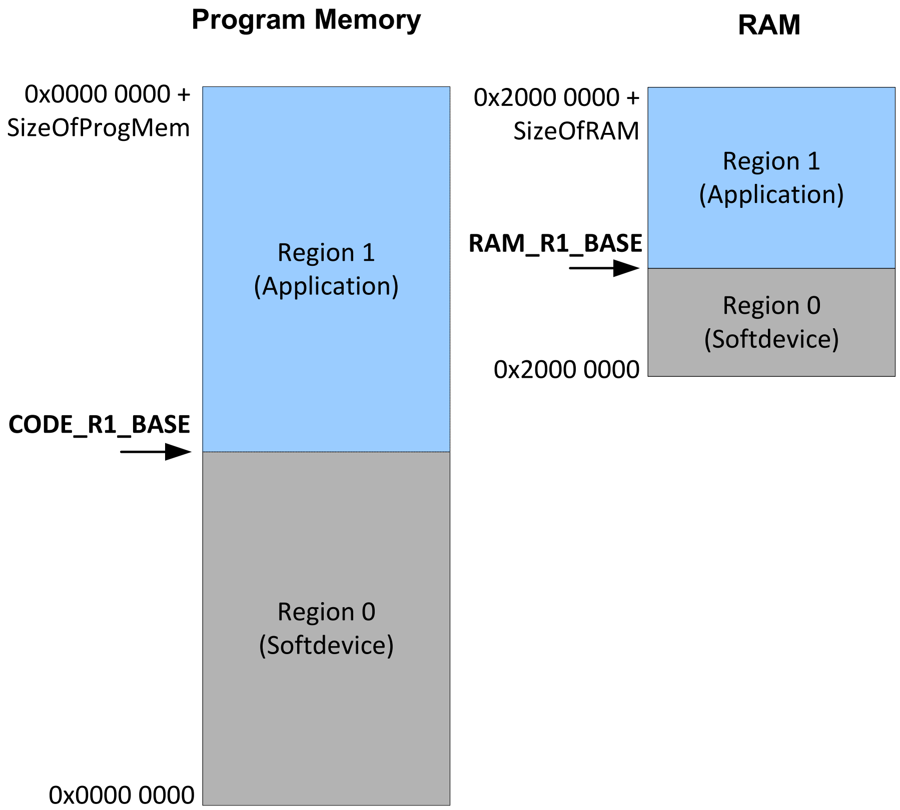


Figure 2 *Memory region designation*

The SoftDevice uses a fixed amount of flash (program) memory. The amount of RAM used is dependent upon whether the SoftDevice is enabled or not. The flash and RAM usage is specified by size (kilobytes or bytes) and the CODE_R1_BASE and RAM_R1_BASE addresses which are the usable base addresses of Application code and RAM respectively. Application code must be located between CODE_R1_BASE and SizeOfProgMem while the Application RAM must be allocated between RAM_R1_BASE and the top of RAM, excluding the allocation for the call stack and heap.

Example Application program code address range:

```
CODE_R1_BASE ≤ Program ≤ SizeOfProgMem
```

---

[1] A sandbox is a set of access rules for memory imposed on the user.

Example Application RAM address range assuming call stack and heap location as shown in:

`RAM_R1_BASE ≤ RAM ≤ (0x2000 0000 + SizeOfRAM) - (Call Stack + Heap)`

Sandboxing protects region 0 memory. Region 0 program memory cannot be written or erased at runtime[2]. Region 0 RAM cannot be written to by an application at runtime. Violation of these rules, for example an attempt to write to the protected Region 0 memory, will result in a system Hard Fault as defined in the ARM® architecture. There are debugger restrictions applied to these regions which are outlined in the *"Memory Protection Unit (MPU)"* chapter in the *nRF51 Reference Manual* that do not affect execution.

When the SoftDevice is disabled the whole of RAM, with the exception of a few bytes, is available to the application. In the context of an enabled SoftDevice however, lower address space of RAM will be "consumed" by the SoftDevice and be marked as write protected.

It is important to note that when the SoftDevice is disabled, the RAM previously used by the application will not be restored. In practice, the application will in many cases want to specify its RAM region from the protected memory length until the end of RAM. This is to make application development easy without having to think about what data to put where.

Note:

- The call stack is conventionally located by the initial value of Main Stack Pointer (MSP) at the top address of RAM.
- By default RAM1 block is OFF in System ON-mode. If the MSP initial value defined in the application vector table is in the RAM1 block, the RAM block will be enabled before the application reset vector is executed.
- Do not change the value of MSP dynamically (i.e. never set the MSP register directly).
- RAM located in the SoftDevice's region will be scrambled once the SoftDevice is enabled.
- The RAM scrambled by the SoftDevice will not be recovered on SoftDevice disable.

Call stack

The call stack is defined by the application. The main stack pointer (MSP) gets initialized on reset to the address specified by the application vector table entry 0. The application may, in its reset vector, configure the CPU to use the process stack pointer (PSP) in thread mode. This configuration is optional but may be used by an operating system (OS), for example, to isolate application threads and OS context memory. The application programmer must be aware that the SoftDevice will use the MSP as it is always executed in exception mode.

In configurations without an OS, the main stack grows down and is shared with the nRF51 SoftDevice. The Cortex-M0 has no hardware for detecting stack overflow, and the application is responsible for leaving enough space both for the application itself and the nRF51 SoftDevice stack requirements.

It is customary, but not required, to let the stack run downwards from the upper limit of RAM Region 1.

---

[2] An exception is replacing the SoftDevice using MBR API functions.

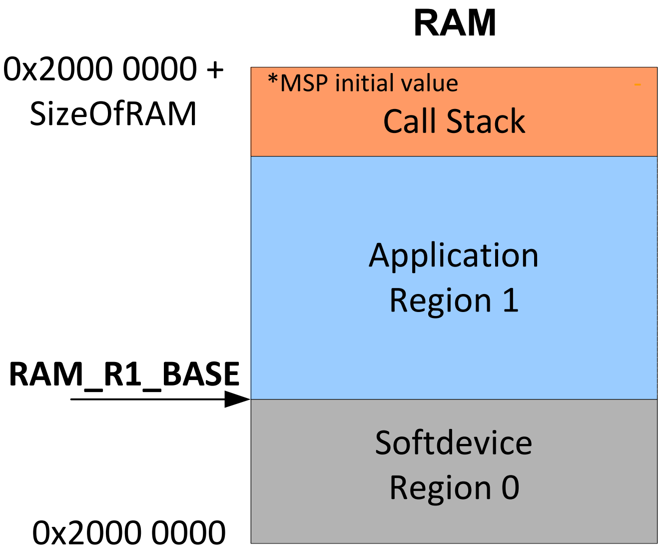


Figure 3 *Call stack location example*

With each release of a nRF51 SoftDevice its maximum (worst case) call stack requirement is specified, see the SoftDevice specification for more information. The SoftDevice uses the call stack when LowerStack or UpperStack events occur. These events are asynchronous to the application so the application programmer must reserve call stack for the application in addition to the call stack requirement for the SoftDevice.

Heap

At this time there is no heap required by nRF51 SoftDevices. The application is free to allocate and use a heap without disrupting the function of a SoftDevice.

Peripheral run-time protection

To prevent the application from accidentally disrupting the protocol stack in any way, the application sandbox also protects SoftDevice peripherals. Protected peripheral registers are readable by the application. As with program and data memory protection, an attempt to perform a write to a protected peripheral will result in a Hard Fault. Note that peripherals are only protected while the SoftDevice is enabled, otherwise they are available to the application. See the SoftDevice specification for an overview of the peripherals that are restricted by the SoftDevice.

Exception (interrupt) management with a SoftDevice

To implement Service Call (SVC) APIs and ensure that embedded protocol real-time requirements are met independent of application processing, the SoftDevice implements an exception model for execution as shown in ***Figure 4*** on page 55. Care must be taken when selecting the correct interrupt priority for application events according to the guidelines that follow. The NVIC API to the SoC Library supports safe configuration of interrupt priority from the application.

The Cortex-M0 processor has four configurable interrupt priorities ranging from 0 to 3 (with 0 being highest priority). On reset, all interrupts are configured with the highest priority (0).

The highest priority (LowerStack) is reserved by the SoftDevice to service real-time protocol timing requirements and thus must remain unused by the application programmer. The SoftDevice also reserves priority 2 (UpperStack (SVC) priority). This priority is used by higher level, deferrable, SoftDevice tasks and the API functions executed as SVC interrupts (see Interface section ***on page 51***).

The application provides two configurable priorities, App(H) and App(L), in addition to the background level - main.

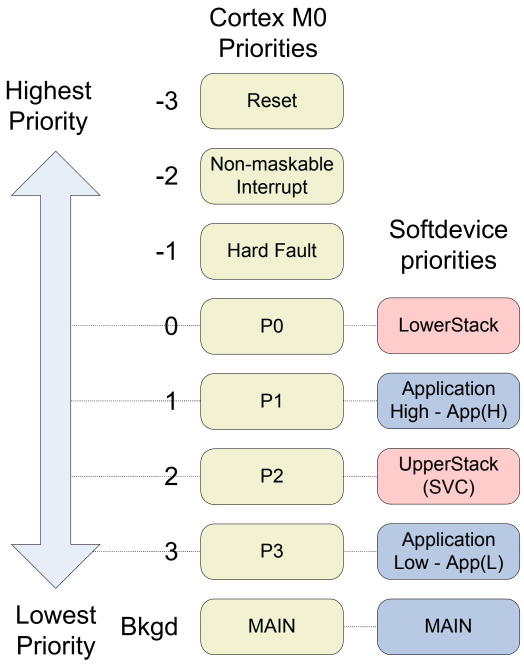


Figure 4 *Exception model*

As seen from the figure, App(H) is located between the two priorities reserved by the SoftDevice. This enables a low-latency application interrupt in order to support fast sensor interfaces. The App(H) will only experience latency from interrupts in the LowerStack priority, while App(L) can experience latency from LowerStack, App(H) and UpperStack context interrupts.

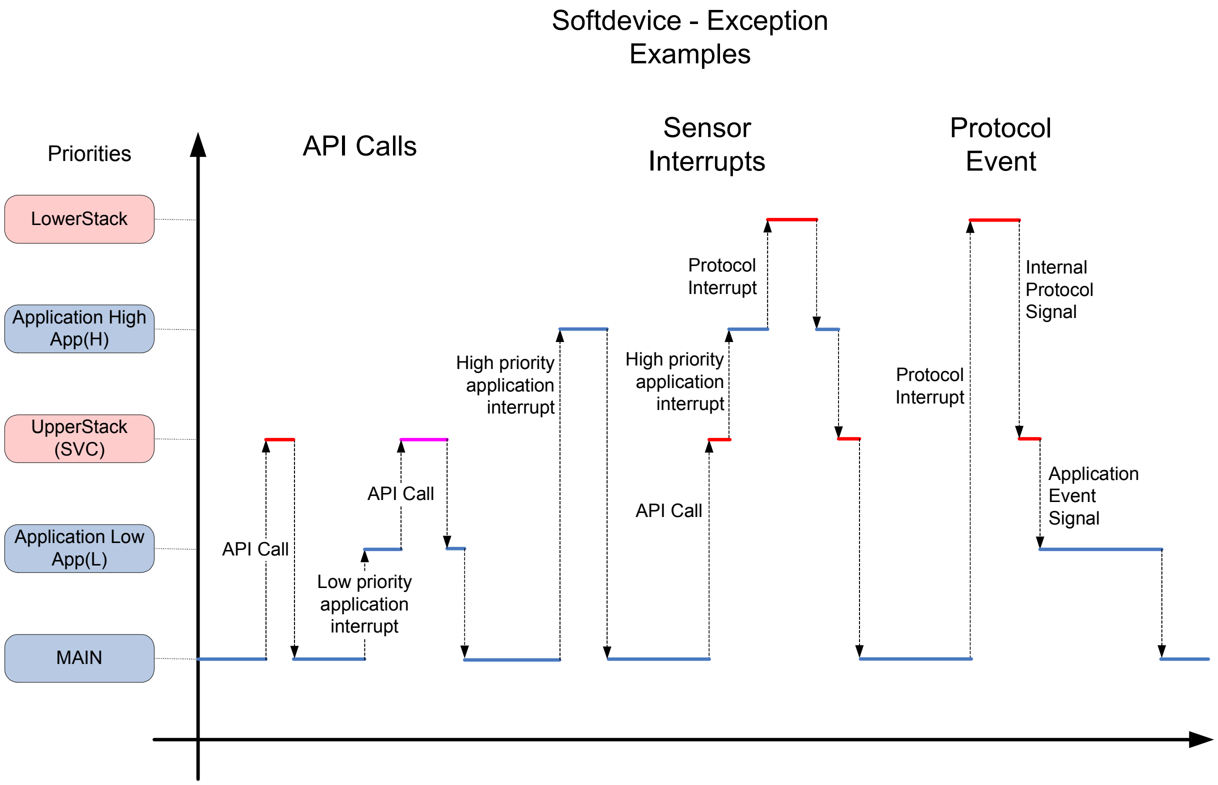


Figure 5 *SoftDevice exception examples*

Interrupt forwarding to the application

At the lowest level, the SoftDevice Manager receives all interrupts regardless of enabled state. When the SoftDevice is enabled, some interrupt numbers are reserved for use by the protocol stack implemented in the SoftDevice and any handler defined by the application will not receive these interrupts. The reserved interrupts directly correspond to the hardware resource usage of the SoftDevice which can be found in the corresponding SoftDevice Specification. For example, if a SoftDevice (or embedded protocol stack) requires the exclusive use of a peripheral “TIMER0”, that peripheral’s interrupt handler can be implemented in the application, but will not be executed while the SoftDevice is enabled.

All interrupts corresponding to hardware peripherals not used by the SoftDevice are forwarded directly to the application defined interrupt handler. For the SoftDevice Manager to locate the application interrupt vectors, the application must define its interrupt vector table at the bottom of code Region 1, see ***Figure 6*** on page 57. The use of a bootloader introduces some exceptions to this, see chapter ***Chapter 10 “Master Boot Record and Bootloader”*** on page 30. In a majority of toolchains, the base address of the application code is positioned after the top address of the SoftDevice. Then, the code can be developed as a standard ARM® Cortex™-M0 application project with the compiler tool creating the interrupt vector table as normal.

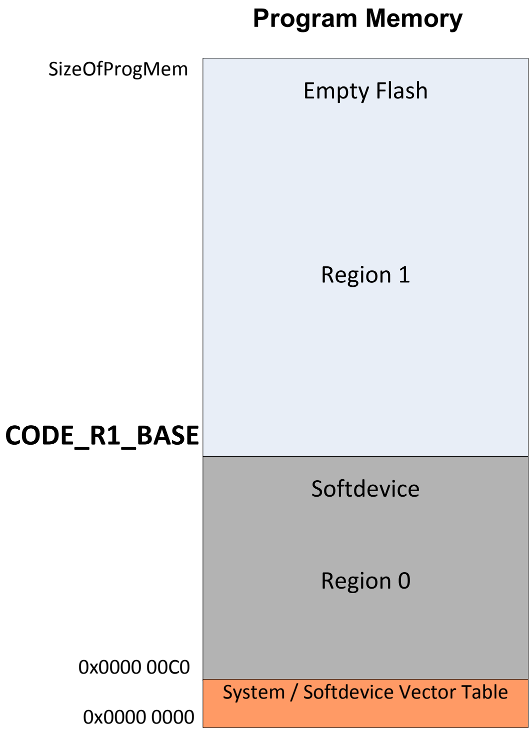


Figure 6 *System and application interrupt vector tables*

SVC interrupt is handled by SoftDevice manager and the SVC number inspected. If equal or greater than 0x10, the interrupt is processed by the SoftDevice. Values below 0x10 cause the SVC to be forwarded to the application. This allows the application to make use of a range of SVC numbers for its own purpose, for example, for an RTOS.

Note: While the Cortex™-M0 allows each interrupt to be assigned to an IRQ level 0 to 3, the priorities of the interrupts reserved by the SoftDevice cannot be changed. This includes the SVC interrupt. Handlers running at Application High level have neither access to SoftDevice functions nor to application specific SVCs or RTOS functions running at Application Low level.

If the SoftDevice is not enabled, all interrupts are immediately forwarded to the application specified handler. The exception to this is that SVC interrupts with an SVC number above or equal to 0x10 are not forwarded.

Events - SoftDevice to application

Software triggered interrupts in reserved IRQ slots are used to signal events from SoftDevice to application. For details on this technique and how to implement handling of these events, refer to the Software Development Kit (SDK) for your device.

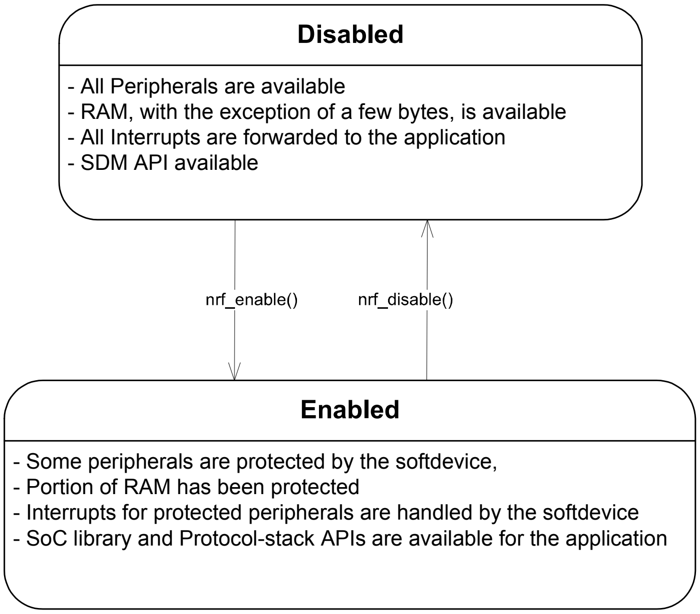
SoftDevice enable and disable

Before enabling the SoftDevice, you cannot use any capabilities of the SoftDevice. This extends to the use of the SoC library and protocol stack functions. All of the chip's resources are freely available to the application, with some exceptions:

- SVC numbers 0x10 to 0xFF are reserved.
- SoftDevice program memory is reserved.
- A few bytes of RAM are reserved.

Once the SoftDevice has been enabled, more restrictions apply:

- Some RAM will be reserved.
- Some peripherals will be reserved.
- Some of the peripherals that are reserved will have a SoC library interface.
- Interrupts will not arrive in the application for reserved peripherals.
- The reserved peripherals are reset upon SoftDevice disable.
- *nrf_nvic_* functions must be used instead of *CMSIS NVIC_* functions for safe use of the SoftDevice.
- Maximum interrupt latency will be determined by the SoftDevice.



Power management

While the SoftDevice is disabled, the application must implement power management at the highest level. After a SoftDevice is enabled, the POWER peripheral will be protected. This means that all interactions with the POWER peripheral must happen through the SoC Library Power API. This API provides an interface for turning on/off peripherals and checking the power status of peripherals that are not protected by the SoftDevice. The application will also have the ability to set the other registers in the peripheral and put the chip in System OFF.

Error handling

All SoftDevice API functions return an error code on success and failure.

Hard Faults are triggered if an application attempts to access memory contrary to the sandbox rules or peripheral configurations at runtime.

An assertion mechanism through a registered callback can indicate fatal failures in the SoftDevice to the application.