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nRF51 SoC Device Firmware Update (DFU)

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Device Firmware Updates (DFU)

- Firmware updates after the product is shipped
  - Bug fixes, new features and improvements
  - Over-the-Air (OTA), wired interfaces (UART, SPI, I2C)
- Nordic is developing an advanced suite of DFU solutions for nRF51 Series ICs and software
  - Flexible – freedom for developers to customize
  - Efficient and safe
- Application space (user code) update
- Bluetooth stack (SoftDevice) update
- Application update released Nov 2013
- Softdevice update is releasing in 2014

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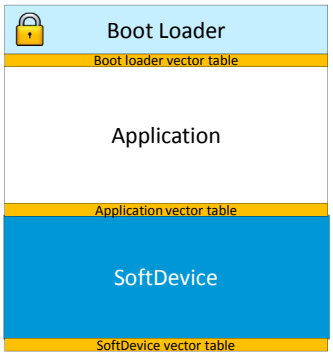
Boot Loader



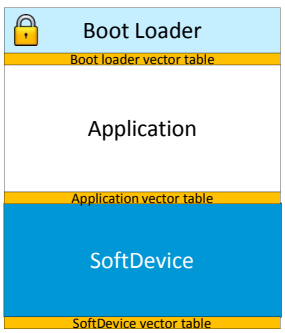
- Where execution starts on reset
  - Write and erase protected
- Manages application update:
  - Controls device
  - Receive and store updates
  - Can use different transports
    - UART, SoftDevice (OTA)
- Available in nRF51 SDK
  - Source code
  - Can be used as is or customised

Application Update

Two methods of update

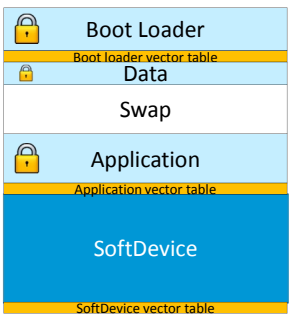
Single Bank Update

Minimum code space overhead



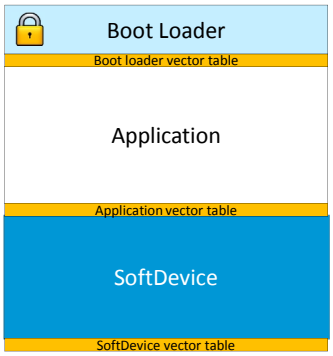
Dual Bank update

Maximum safety



Single Bank update

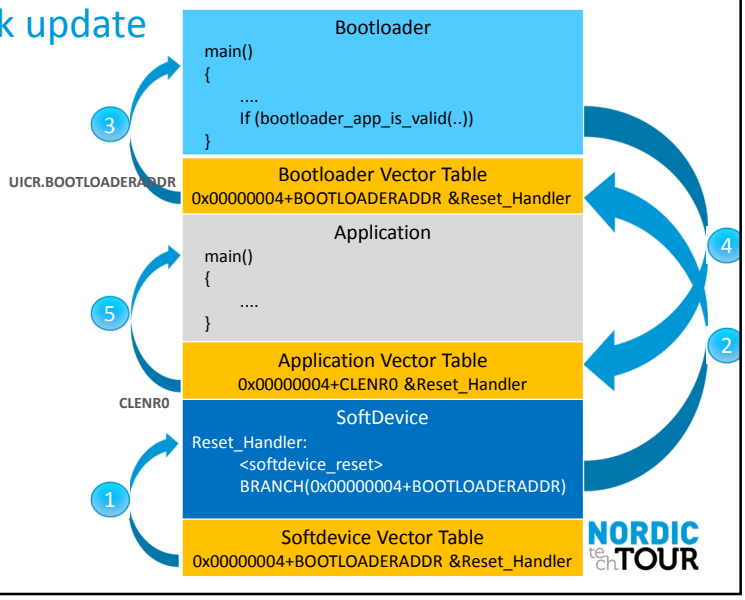
Application



- Current single bank bootloader:
  - Using UART transportation
  - Supported from nRF51 SDK v4.4.0
  - Code size of bootloader 11.4KB
- Max application size:
  - App = Flash size - Softdevice - Bootloader
    - nRF51822 XXAA (256 kB): 164 kB
    - nRF51822 QFAB (128 kB): 36 kB

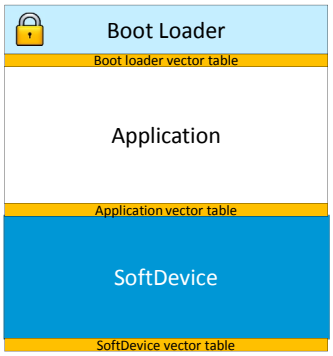
Single Bank update

Booting process



Single Bank update

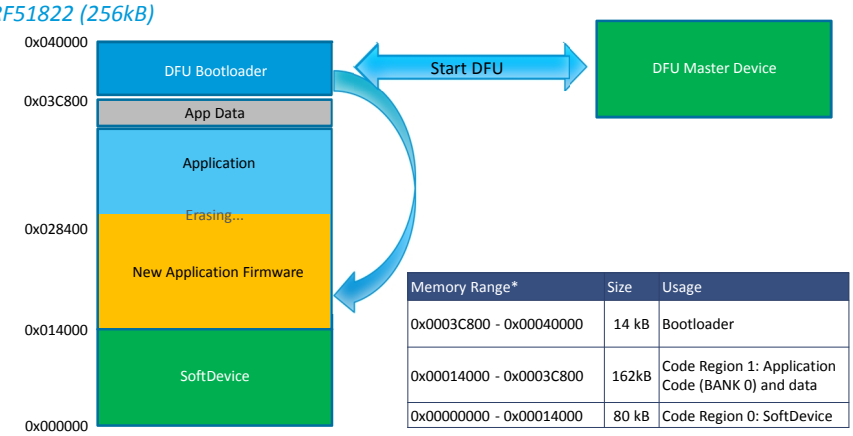
Performance



- UART baud rate supported:
  - nRF51 SDK example: 38400 baud
  - nRF51 SDK transport layer can do 1Mbaud
  - Production friendly, same interface as BT Direct Test Mode
- Transfer speed
  - 20 kB application (e.g. HRM) @ 38.4 kbaud: **4.1 sec**
  - 164 kB (full app space) @ 38.4 kbaud: **34.6 sec**
  - 164 kB @ 1 Mbaud: 1.3 sec
- Peer side DFU tool provided:
  - Windows command line utility
  - nRFgo studio

Application firmware update

nRF51822 (256kB)

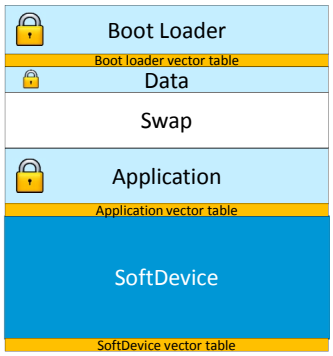


Memory Range*	Size	Usage
0x0003C800 - 0x00040000	14 kB	Bootloader
0x00014000 - 0x0003C800	162kB	Code Region 1: Application Code (BANK 0) and data
0x00000000 - 0x00014000	80 kB	Code Region 0: SoftDevice

*The memory layout is the layout from the DFU SDK example that is generic and can be adjusted

Dual Bank update

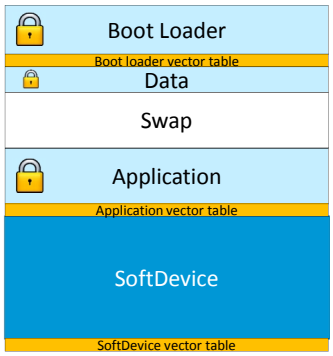
Application



- Dual Bank update:
  - UART interface or OTA via BLE
  - Bootloader writes new FW to swap space
  - When transfer is complete, new FW is copied to Application space and update is complete
- Characteristics:
  - 2x code space required for swap and app
  - If update fails, the boot loader can fall back to the original and still valid application
  - Device is never "stalled"
  - Maximum safety

Dual Bank update

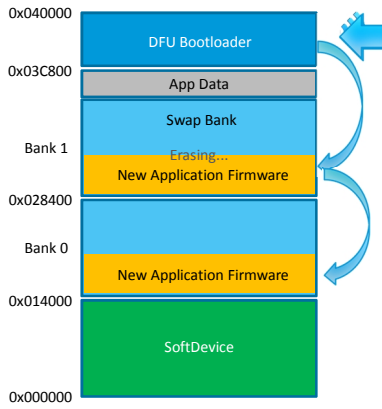
Via BLE

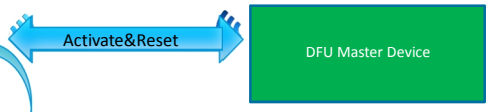


- Dual Bank update via BLE:
  - Swap enables reverting to old firmware if BLE link is permanantly lost
- Supported from nRF51 SDK 4.4.0 (Aug 2013)
  - Code size for DFU Bootloader over BLE: 13 kB
- Max App size dual bank update:
  - App size = (memory – SD – boot loader) /2
    - nRF51822 xxAA (256 kB): 81 kB
    - nRF51822 QFAB (128 kB): 17 kB

Dual Bank update

Application firmware update on a 256KB nRF51822



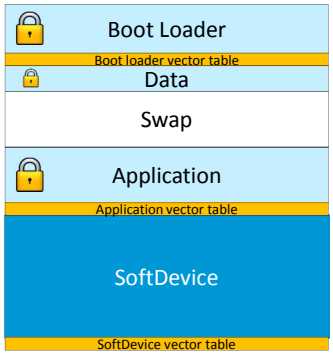


Memory Range*	Size	Usage
0x0003C800 - 0x00040000	14 kB	Bootloader
0x00014000 - 0x0003C800	162kB	Code Region 1: Application Code (BANK 0), Swap (BANK 1), and data
0x00000000 - 0x00014000	80 kB	Code Region 0 –SoftDevice

*The memory layout is the layout from the DFU SDK example that is generic and can be adjusted

Dual Bank Update in nRF51 SDK

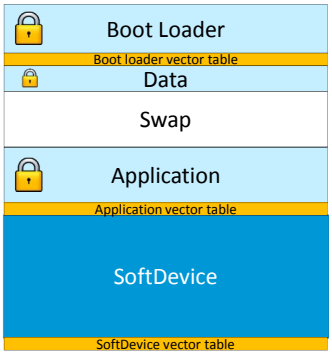
Performance



- BLE DFU service details:
  - Connection Interval (SDK 4.4.0): 11.25 ms
  - Maximum 3 packets pr connection interval
  - 20 bytes / packet
- Update times:
  - nRF Master Emulator (Peer as fast as SDK):
    - 20 kB application (eg. Heart Rate): **5 sec**
    - 80 kB application: 15 sec
  - Android 4.3+: **15 sec** (20 kB)
  - iOS7: **7 sec** (20 kB)

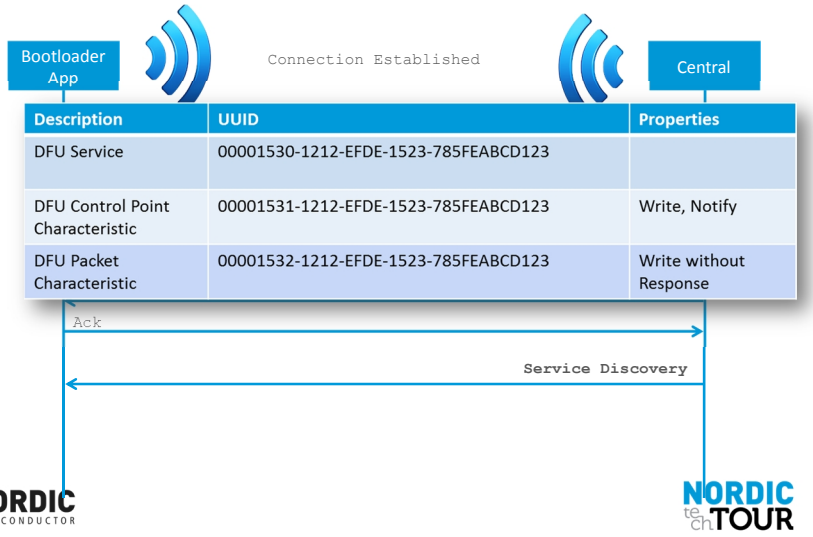
Dual Bank Update in nRF51 SDK

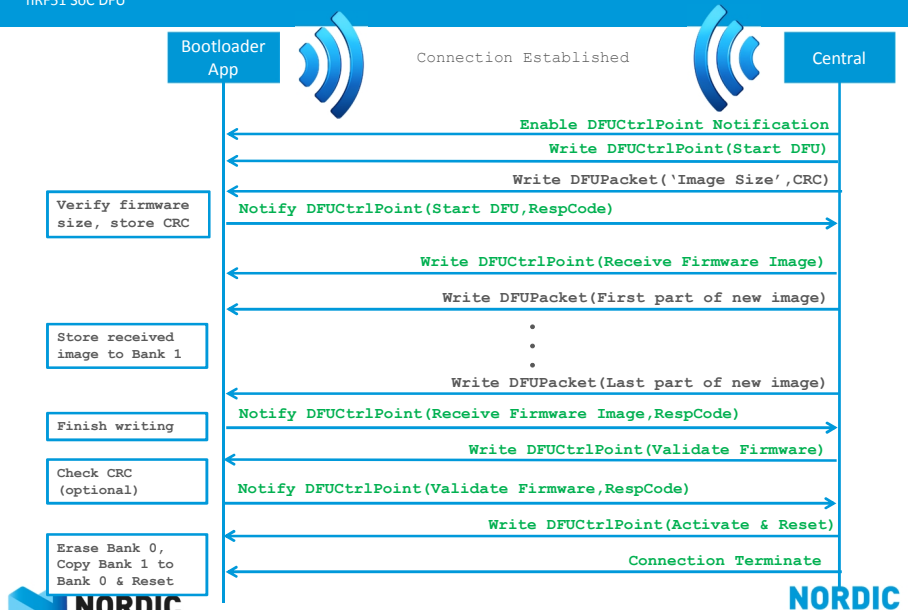
SAFETY



- Link Loss Recovery Mechanism
  - Upon re-connection Peer issue a «Request Received Image Size»
  - Continue data transfer if remote and local image size doesn't match
- Recovery from incomplete/failed Firmware Update
  - Old application preserved until successful Firmware Update completed
  - Fallback to original application
  - Old application will be re-started after 60s time out

Over the air firmware update sequence





Central solutions

New FW has to arrive from somewhere…

- Windows 7 and 8: **nRF master control panel**
  - Use Master Emulator included in nRF51 DK and EK
  - Win8 native stack support – on roadmap
- Android 4.3+ : **nRF ToolBox – DFU, nRF Master Control Panel**
  - Nordic developed App available from playstore early Nov 2013
  - Use native BLE stack in Android
  - Matches dual bank update in nRF51 SDK
  - Source code available
- iOS7: **nRF Loader**
  - Nordic developed App available from App store, late Nov 2013
  - Uses native BLE stack in iOS7
  - Matches dual bank update in nRF51 SDK
  - Source code available

Competitive Benchmark

nRF51 DFU:

- 11.25 ms connection interval
- 20 bytes pr packet
- 3 packets pr connection interval
- nRF51 SDK proximity example : 18kB
  - **Update: 5 sec**
- Full App bank update ~80 kB
  - **Update: 15 sec**
- Confirmed by measurements

CC254x OTA:

- 30 ms connection intervals
- 18 Byte pr. packet
- 1 packet pr conn interval
- TI SDK examples:
  - Keyfob: 116 kB
  - Blood glucose: 132 kB
  - OAD (upgrade image): 114 kB
- OAD image: ~114kB
  - **Update: ~3 min**
- Confirmed by measurement

Dual Bank Update

Apple to Apple comparison

nRF51 DFU:

- 30 ms connection intervals
- 20 bytes / packet
- 6 packets per connection (verified through sniffer)
- Data Rate = $\frac{1}{0.03}$ x 20 x 6 = 4.0KB/sec
- HRS application (eg. Heart Rate): 18kB
  - **Update: 7.6 sec (measurement).**

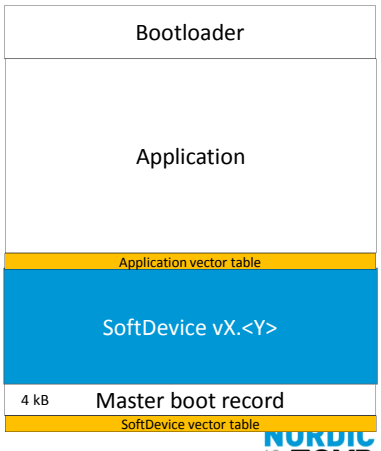
CC254x OTA:

- 30 ms connection intervals
- 18 Byte pr. packet
- 1.5 packet pr conn interval (verified through sniffer)
- OAD image: ~114kB
  - Update: ~3 min (measurement)
  - (3 x 60)/114 = 1.579s/kB
  - **Update: 1.579 x 18 = 28.4 sec (estimation)**

SoftDevice Update

Complete SoftDevice Update

- Add a "Master boot record" under the Softdevice in code region 0 to handle flash updating
- Softdevice and/or application update:
  1. Erase App firmware
  2. Store new SoftDevice and bootloader to app space
  3. Erase old SoftDevice and bootloader
  4. Write new SoftDevice and bootloader
  5. Erase SoftDevice from Application
  6. Boot with the new bootloader
  7. Download new App into app space and run
- Not Dual Bank because:
  - SoftDevices' size could be too large to have a swap bank.
  - nRF51 DFU proven stable
  - Data integrity mechanisms ensures safe update

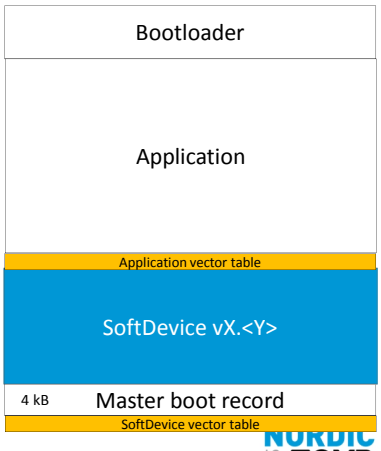


nRF51 SoC DFU

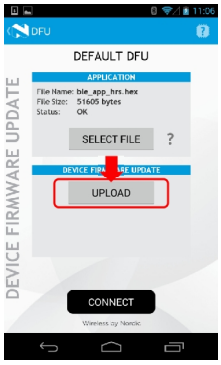
SoftDevice Update

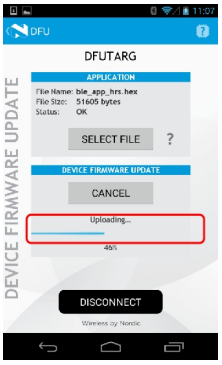
Complete SoftDevice Update

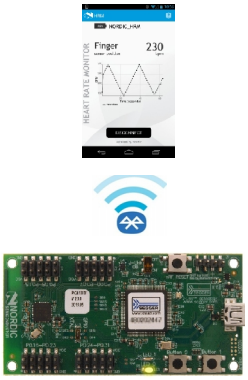
- **PROs:**
  - Full SoftDevice update
    - Bug fixes **as well as** feature updates!
  - Full application upgrade
    - Can use new SD features!
  - Softdevice update and application update are integrated.
  - Bootloader update
- **CONs:**
  - 4kB flash used for Master boot record to handle flash updating



Demo







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