DWM1001 Firmware User Guide

DWM1001 Firmware User Guide

Based on DWM1001-DEV board

Version 1.1

This document is subject to change without notice

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    (b)   The **Decawave DRTLS Manager** which is an Android™ application for configuration of DRTLS nodes (nodes based on the Module) over Bluetooth™.

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        • DRTLS Gateway Daemon
        • DRTLS Gateway MQTT Broker
        • DRTLS Gateway Web Manager

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1 INTRODUCTION

1.1 Overview

The development of real-time positioning network using UWB technology is not a trivial project. The intention of DWM1001 is to simplify the development of UWB RTLS by providing a complete solution in a single module.

The DWM1001 module comes pre-loaded with embedded firmware which provides two-way ranging (TWR) real time location system (RTLS) functionality and networking. The module can be configured and controlled via its API, which can be accessed through a number of different interfaces allowing flexibility to the product designer. The details of the API is described in document [2]. Additionally, Decawave also provide the module firmware in form of libraries and source code along with a build environment so that user can customise the operation and/or add their own functions.

This document describes what is included in the DWM1001 firmware and how these various elements cooperate together, and explains how users can add their own customisations. The aim of this user guide is to help the users with their development based on the DWM1001-DEV board. After reading this guide developers should be able to compile, build and run the DWM1001 firmware, including custom modifications.

1.2 What's included in the firmware release

Each DWM1001 firmware release includes:

1) The pre-compiled DWM1001 Firmware, including the firmware Positioning and Networking stack (PANS) library for on-board development, is provided in the DWM1001 on-board package. The firmware and library architecture and its basic partitioning are described in Section 2.
2) Firmware tool chain, described in Section 3. The detailed steps to prepare the necessary tool chain, download the firmware user application package, and compile/build/flash their own application are introduced.
3) Simple examples demonstrating how to use the DWM1001 APIs. These are described in Section 4.

2 FIRMWARE OVERVIEW

2.1 High-Level Architecture

The firmware embedded in the DWM1001 module basically provides two types of functions: the PANS API and the PANS library which provides lower level functions. The PANS API, includes the Generic API, (these include different API sets for different interfaces and the corresponding parser, which acts as the translator between the user APIs (C, UART, SPI and BLE) and the PANS library). Figure 1 shows the architecture and components of the DWM1001 firmware.
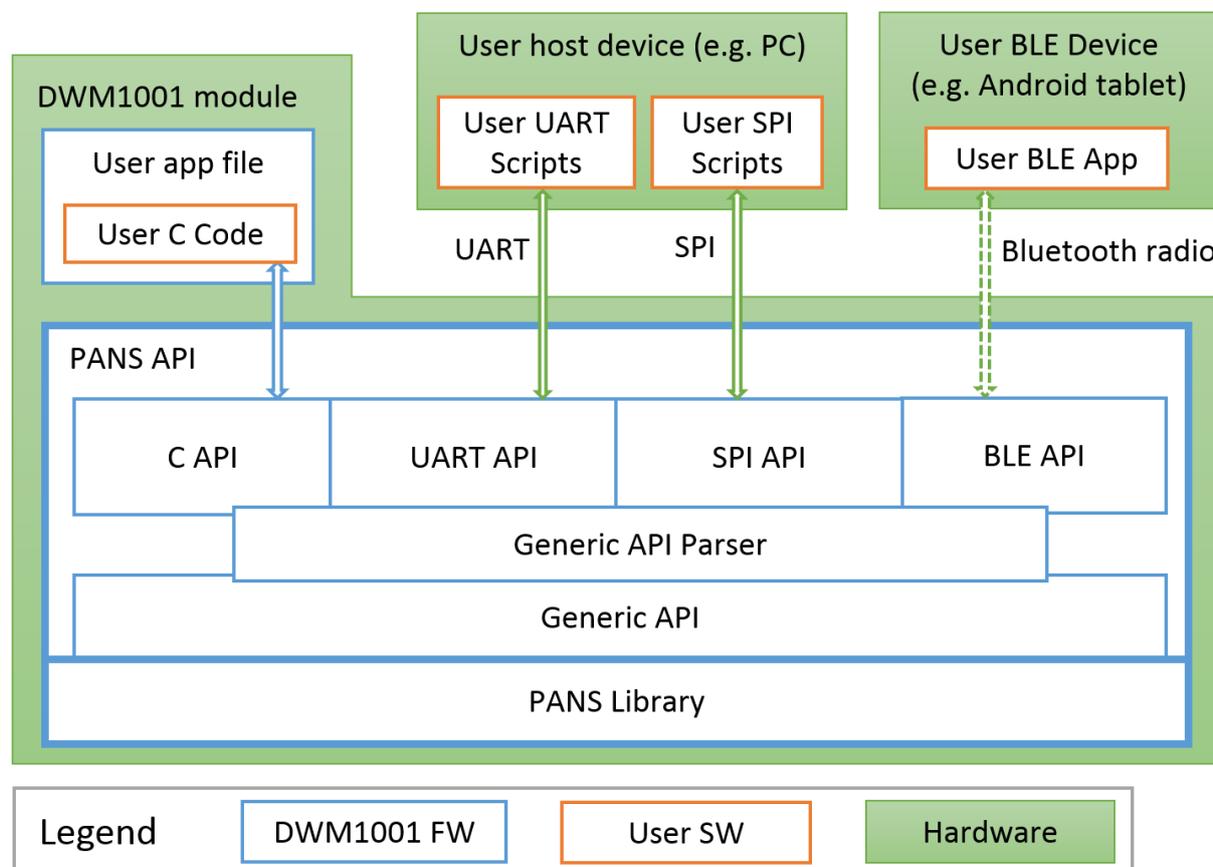

Figure 1 High-Level Architecture of DWM1001 Firmware vs. User Software

As can be seen in Figure 1, apart from using the DWM1001 module itself, the DWM1001 module can be physically connected to external controlling hardware, either wired or wirelessly over Bluetooth radio. The PANS API provides the users with four sets of API to call the PANS library functions through different interfaces:

- **User C code:** an on-board user space, allowing to include an application-specific code in the user application file provided in the DWM1001 firmware, using the firmware development tool chain provided by Decawave, see Section 4.2.

- **SPI:** using a host device (e.g. PC) to communicate with the DWM1001 module using TLV (Type-Length-Value format, detailed in [2]) format requests and responses through SPI bus, for configuration and data transmission.

- **UART:** using a host device (e.g. PC) to communicate the DWM1001 module through UART bus, for configuration and data transmission. Two modes of communications

are provided over the UART interface: UART Generic mode using TLV format requests and responses; and UART Shell mode using terminal prompt commands.

- **BLE:** using a Bluetooth Low Energy (BLE) device (e.g. Android tablet) to control and configure through Bluetooth radio.

All these API sets provide the same set of generic functions calls, namely the Generic API. The Generic API Parser acts as the translator between the four API sets and the Generic API. When an API command is called from any of the above API Interfaces, the command goes through the Generic API Parser which translates the API command into Generic API function calls. If the API command needs a return message, the DWM1001 responds through the same interface.

The use of C code, UART and SPI APIs are detailed with simple examples in Section 4. More detailed information is provided in the API document [2].

Note1: The external interfaces, including the UART, the SPI and the BLE, are used by the external APIs in the PANS library for Host connection. The on-board user application through C code API cannot make use of the external interfaces due to compatibility reasons.

Note2: Decawave do not provide the library source code, or support any use of the PANS library except through the PANS API which is described in the API Document [2]

2.2 Overview of the PANS Library

Figure 2 illustrates the architecture of the PANS Library in detail. From bottom up there are the SoftDevice and the BLE Protocol stack from Nordic Semiconductor, eCos RTOS system with embedded drivers of the components, IoT layer protocols and the applications layer. Section 2.3 gives a brief introduction to each of the components in the library and the operations on the application layer.
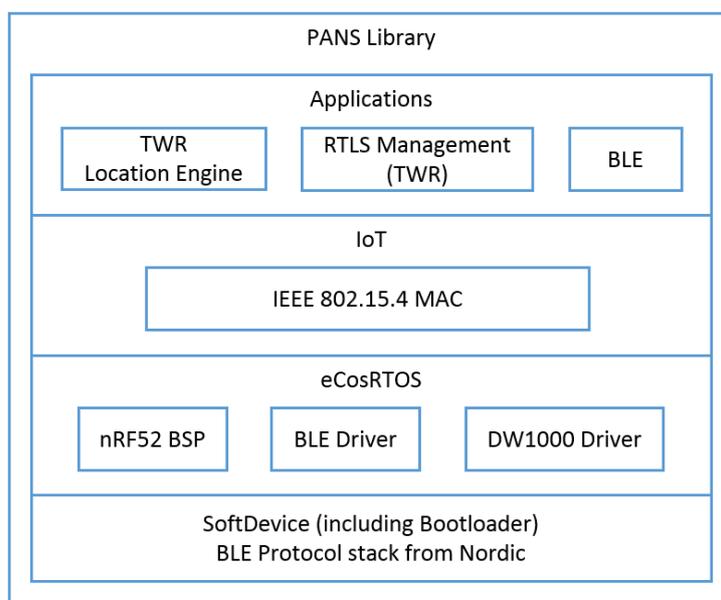

Figure 2 DWM1001 Firmware LibraryComponents

2.3 Components and operations of the PANS Library

The PANS library includes a few firmware components to drive the DWM1001 module.

Some operations are implemented based on these components to perform the positioning and networking function.

2.3.1   SoftDevice and BLE driver

SoftDevice is a Nordic Semiconductor feature-rich library for BLE. The SoftDevice employed on the DWM1001 is the S132, a concurrent multi-link SoftDevice for Central, Peripheral, Broadcaster and Observer roles in BLE applications. The BLE driver / library is included in the S132 SoftDevice, providing the DWM001 with BLE features to create complex network topologies, communication and firmware update over-the-air [1].

2.3.2   eCos RTOS and BSP

eCos RTOS is a free open source real-time operating system. The eCos system provides very good run-time performance and the board support package (BSP) for the DWM1001 hardware platform. It includes all the necessary drivers for the module components (i.e. accelerometer, BLE & DW1000).

2.3.3   DW1000 driver

Decawave's DW1000 API driver. For details please see DW1000 Software API Guide [2].

2.3.4   Stationary indication

An accelerometer component LIS2DH12TR of slave address 0x19 as an I2C peripheral device is implemented on the DWM1001 module, i.e. the read and write address are 0x33 and 0x32 respectively. This accelerometer provides a simple "stationary" indication function. The DWM1001-based tag can be configured to use *Responsive* or *Low-Power* mode. It will be in *Low-Power* mode when stationary, and will enter *Responsive* mode when moving. The real-time accelerometer data is accessible through provided Shell API command and I2C functions in the C code API, see [2] for detailed information.

2.3.5   DRTLS Network operation

The DWM1001 TWR Real Time Location System (DRTLS) networking stack, allows discovery, joining and leaving. The UWB frames are sent according to 802.15.4 standard frame formats. The MAC layer functionality implemented on the DWM1001 module, as described in DWM1001 System Overview document [3], controls the mechanism for joining, leaving, installation, commissioning of nodes and associated two-way ranging protocol and data transfer. A number of different use cases e.g. follow-me, large-scale asset-tracking, navigation, home network are supported.

2.3.6   Commissioning

DRTLS can be commissioned with Decawave RTLS Manager Android application. After power on, new nodes will advertise over Bluetooth. Decawave RTLS Manager application is used to connect to the node and configure it (e.g. its role as anchor or tag; its x,y,z coordinates if it is an anchor and other attributes).

2.3.7   RTLS Management

The RTLS Management application supports configuration of DWM1001 modules as tags and anchors which will participate in TWR. The tags will range to nearby anchors and use internal location engine to calculate position. The full implementation is detailed in the DWM1001 System Overview document [3].

2.3.8   TWR solver / Location Engine

The TWR solver / Location Engine in the tags calculates tag's x, y and z, coordinates is implemented on the DWM1001 module. TWR results between the tag and the relative anchors are sent to the solver for the calculation of tag's position. The TWR results are accessible through the APIs. The internal location engine can be disable and user customised location calculation performed instead, e.g. adding extra filtering of change LE/solver algorithms.

3 FIRMWARE TOOL CHAIN

3.1 Tool Chain Overview

The Decawave firmware tool chain includes the following parts:
- Virtual Box image with necessary tools pre-installed;
- DWM1001 on-board package.

These can be used for developing of a new application with added new functionality which will reside in the DWM1001 module and will run on top of the PANS library and the main module functionality.

3.2 Content in the tool chain

The Figure 3 below shows the tool chain used in the DWM1001 firmware development.

In the DWM1001 product, the whole firmware development is under Linux (Ubuntu) virtual machine (VM). Apart from the Linux system itself, the VM includes the tools for development: GCC (arm-none-eabi-gcc version 5.4.1), OpenOCD (version 0.10.0) and Eclipse (version Oxygen Release 4.7.0). The distributed DWM1001 on-board package contains the user app source files and the libraries needed to compile and build the DWM1001 user firmware.
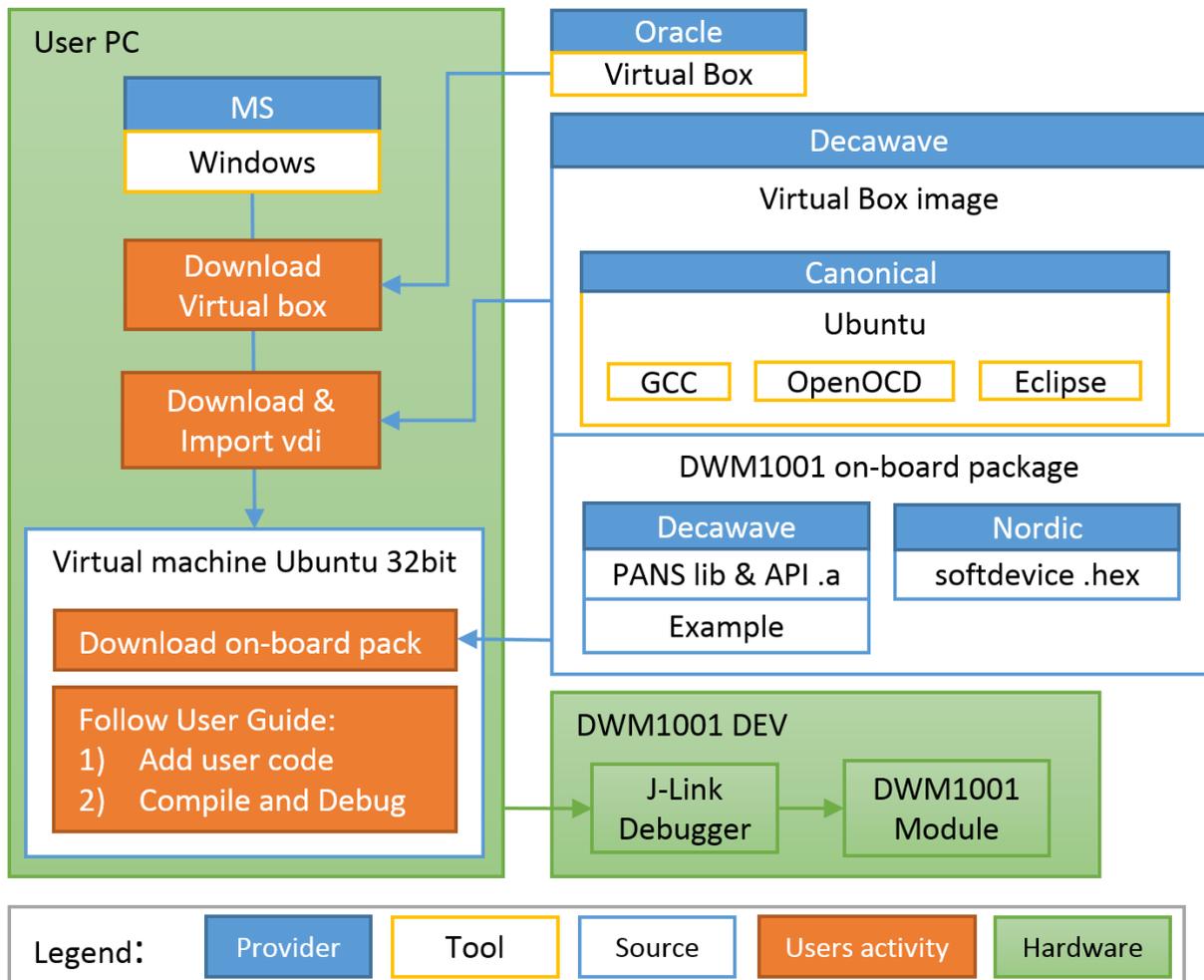
Figure 3 Tool chain and source components in DWM1001 firmware development

3.2.1 Hardware part of toolchain

As illustrated in green color in Figure 3, a PC with Microsoft Windows OS and a DWM1001-DEV board are required as the hardware. The DWM1001-DEV board provides the DWM1001 module as the target and a J-Link debugger.

3.2.2 Software part of toolchain

In the DWM1001 firmware development, two types of tools are used:

1) Microsoft Windows tools – which need to be downloaded by the users;

2) Linux tools – which Decawave have prepared in the Linux VM image.

On the Windows PC, the Virtual Box provided by Oracle needs to be installed. The 32-bit Linux image provided by Decawave needs to be downloaded and imported into the Virtual Box as a VM as introduced in Section 3.3.2.

On the Linux VM, Decawave have prepared the required tools to compile, debug and download the firmware onto the DWM1001 module, including GCC, J-Link and eclipse tools. Decawave would recommend using the pre-installed software tools, since using different versions of the above tools may cause unexpected errors. Decawave do NOT provide any guidance on the installation of the software tools under Linux environment.

3.2.3 Example application package for DWM1001

The DWM1001 on-board package is provided for download on Decawave website [7].

The on-board package includes the DWM1001 PANS library, the Nordic Semiconductor softdevice binary image and the on-board user application example files.

In DWM1001 firmware, the eCos library and other third party software constitute the PANS library as introduced in Section 2.2. These source files are not provided in the on-board package. Folder dwm\examples\dwm-simple is the provided on-board user application folder for adding user customized functions through the C code APIs.

3.3 Guides to flash the DWM1001 with factory image

DWM1001 comes with pre-flashed factory image of firmware. This image is provided in the DWM1001 on-board package: /dwm/recovery/dwm1001-flash.hex. Here the guide to flash the factory image through the DWM1001 DEV board is provided.

3.3.1 Using J-Flash Light

The J-Flash Light tool can be used to flash the factory image through the DWM1001 DEV over a few different platforms.
1) Prepare j-link tool
    a. Download J-Link software from https://www.segger.com/
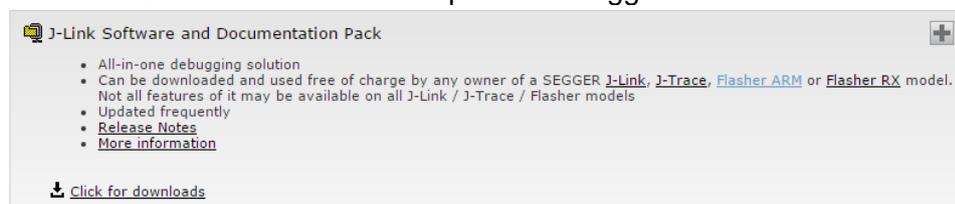
    b. Install J-Link software.

2) Connect the module with a micro USB data cable, shown in Figure 4.
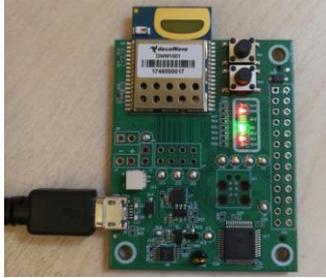
Figure 4 DWM1001 DEV board – micro USB connection

3) Flash the image DWM1001 module
   a. Open J-Flash Lite (default path is similar to in C:\Program Files (x86)\SEGGER\JLink)
   b. Choose nrf52832_XXAA as Device and SWD as interface, use default speed 1000. Click "OK".
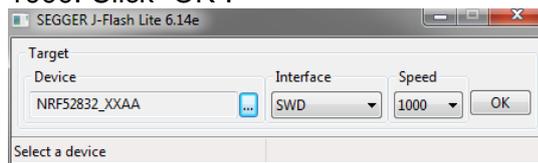
   c. Click "Erase Chip" to do a full chip erase.

   d. In Data File, click and browse to the hex file provided in the DWM1001 on-board package (/dwm/recovery/dwm1001-flash.hex) to flash, click "Program Device".
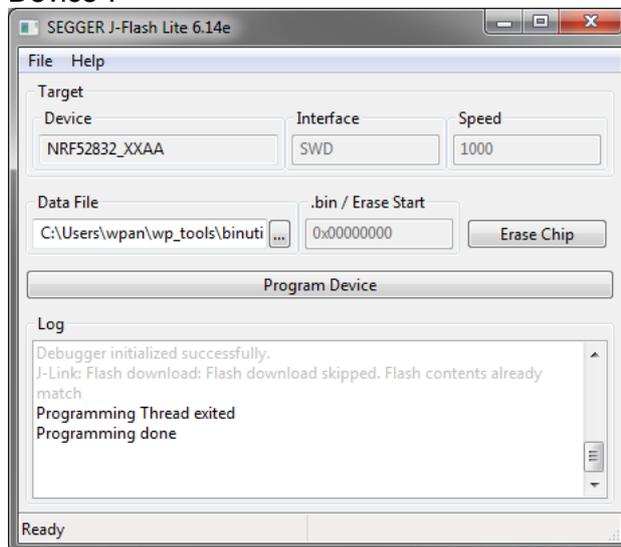
The LEDs on the boards should be active once the flash update completes.

3.3.2 Using the provided VM tools

The provided VM tools can be used to flash the factory image onto a DWM1001 module. The necessary steps are listed here.

1) Install Oracle VM VirtualBox [5].
2) Download the DWM1001 VM image package [6] and extract.
3) Mount the image in VirtualBox Manager. Note that the VM running performance can be improved by increasing the number of processors, RAM and Disk etc.
   a. Go to the menu bar → Machine → Add…

b. Find Decawave_DWM1001_VirtualBox_Image.vbox file extracted from the package, and click "Open".

c. If a faster speed of the VM is desired, select the created virtual machine "Decawave_DWM1001_VirtualBox_Image", click "Settings" on the menu bar → System. In Tabs Motherboard and Tab Processor, adjust the suitable amount of memory and processors assigned to the VM. Click "OK" when this is done.
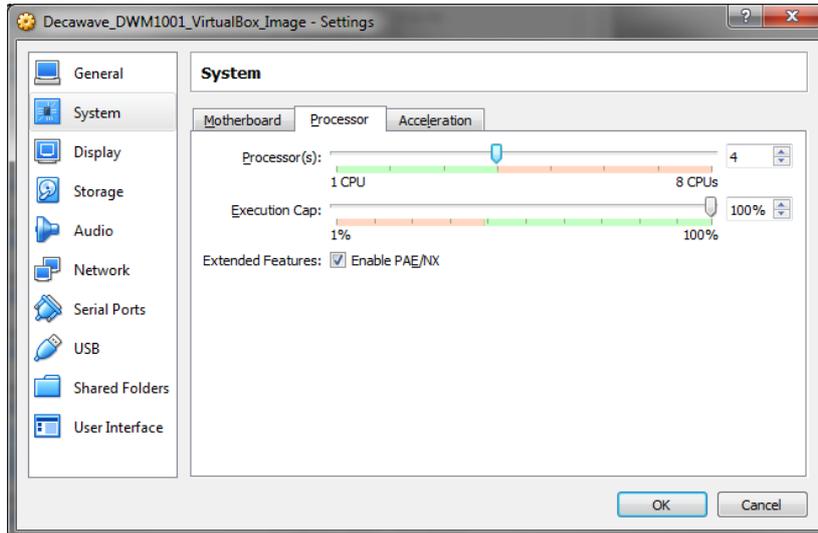
d. Click "Start" on the menu bar and the virtual machine will start.

e. Use password "dw" to login the virtual machine.

4) Download the DWM1001 on-board package into ~/Documents. To do this, either downloading directly in the Linux virtual machine or using a shared folder to transmit from the host system (Windows) can work.

a. In the Linux virtual machine, download the DWM1001 on-board package from [7] into ~/Documents folder using wget command and unzip command.

   ➢ cd ~/Documents

   ➢ wget web/link/to/dwm1001_on-board_package_v1p0.tar

   ➢ tar xf dwm1001_on-board_package_v1p0.tar

b. Alternatively setup a shared folder to transmit files between the host Windows system and the Linux virtual machine:

   i. In Windows, create folder with name "share_folder", download the DWM1001 on-board package and extract it into this folder.

   ii. In Virtual box settings, create shared folder using the "share_folder" in Windows. Use auto mount and permanent.

   iii. Restart the Linux virtual machine, the shared folder will show up in /media/sf_share_folder .

   iv. In Linux virtual machine, copy the files from /media/sf_share_folder into ~/Documents.

Note: by doing either way above, make sure that the extracted on-board package path looks like ~/Documents/dwm/ .

5) Connect the module with a micro USB data cable, see Figure 4 in Section 3.3.1.

6) Go to VirtualBox Menu bar → Device → USB → Click SEGGER J-Link
Make sure there is a √ before SEGGER J-Link, the device used in DWM1001 DEV board. Having a √ in front means the device control is now on the VirtualBox side rather than on the Windows side. See Figure 5.
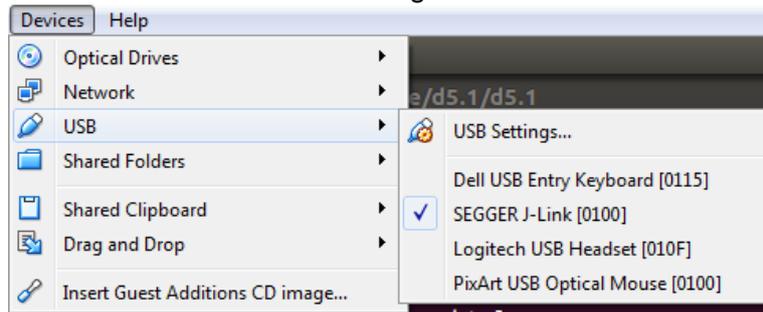
Figure 5 Transfer DWM1001 from Windows to VirtualBox

7) Run the script to fully erase the DWM1001 module and flash the module with factory image:
   ➢ cd ~/Documents/dwm/examples/dwm-simple
   ➢ make recover
The LEDs on the boards should be active once the flash update completes.

4 USER APPLICATION EXAMPLES

4.1 Overview

As illustrated in Figure 1, DWM1001 provides many ways to use its API functions. Examples that show the use of the APIs are listed in this section. In C code, UART Shell, UART Generic, and SPI, examples of getting the location of the node through the API are presented. The API document [2] provides more detailed information.

A tool to open serial port between host device and the DWM1001 module over UART is needed in the firmware development. In Windows, PuTTY can be used; in Linux, minicom can be used. The UART baud rate on the DWM1001 module is 115200 bps.

4.2 "C code API" application example

The VM image [6] in the DWM1001 tool chain has pre-installed Eclipse IDE which will be used for debugging the example below. "C code API" example is an application, which is running as part of the on-board firmware, utilizing a system resources of built-in to the module Cortex M4F microcontroller. The application is running as a thread application in multi-thread environment, driving by included to the PANS library eCos real-time operation system.

4.2.1 Firmware image partitioning

The flash size of the MCU (nRF52832) used on the DWM1001 module is 512KB from address 0 to 0x80000. The partitioning of the flash is illustrated as in Figure 6.
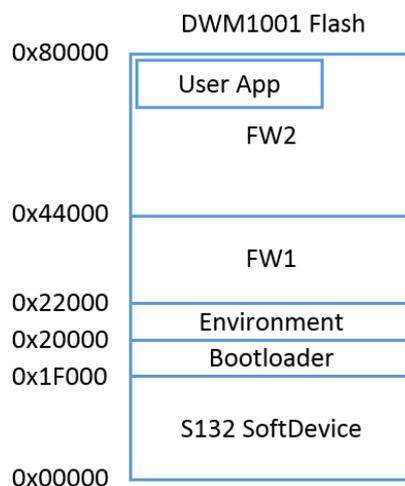
Figure 6 DWM1001 Flash Address Map

The DWM1001 firmware includes the following parts: Nordic S132 Softdevice, Bootloader, Environment, FW1 and FW2:

- **Softdevice**, of size 124KB starting from address 0, provides Bluetooth low energy central and peripheral protocol stack solution.

- **Bootloader**, of size 4KB start from address 0x1F000, is a firmware manager controlling the choice of FW1 and FW2 during booting/reseting.

- **Environment**, of size 8KB start from address 0x20000, is a flash section reserved for the firmware to store user configuration information. Doing power off/on, reset or

firmware re-flash will not clear the Environment section in the flash. To clear the environment section, a full-erase operation introduced in Section 3.3 is needed. Or alternatively, a shell command "frst" introduced in the PANS API [2] can be used.

- **FW1**, of size 136KB starting from address 0x22000, is a piece of firmware for the over-the-air (OTA) firmware update.

- **FW2**, size of up to 240KB starting from address 0x44000, is the firmware image that includes the full PANS library and the c code user application, where the user application is acting as an independent thread in the firmware and can occupy up to 3KB RAM and 60KB Flash. When rebuilding/reflashing the user application firmware, the whole FW2 is being operated.

4.2.2 Compiling/debugging user application in the firmware

To add user customized features, the user customized code needs to be added to the application files and the whole project needs to be re-built. A simple example of making a C code user application is given in example/dwm-simple/dwm-simple.c. The detailed steps of setting up the building and compiling with the provided tool chain is listed here.

1) Install the VM tools and download the DWM1001 on-board package as introduced in Section 3.3.2.
2) Open Eclipse
   a. In the VM, double click Eclipse IDE label on the Desktop
   b. Alternatively, Eclipse IDE can be found in /data/tools/eclipse folder.
3) Import the dwm project:
   a. In Project Explorer view → Right click → Import…
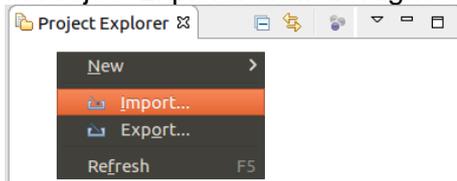
   b. General → Existing Project into Workspace→ Next
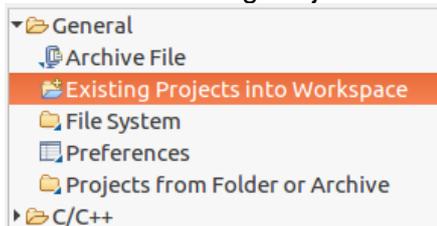
   c. Select root directory → Browse… → find /home/dw/Documents/dwm → OK. Note: project path may vary according to users' local setup.
   d. Tick the "copy projects into workspace" option so a copy of such project will be created in ~/workspace folder.
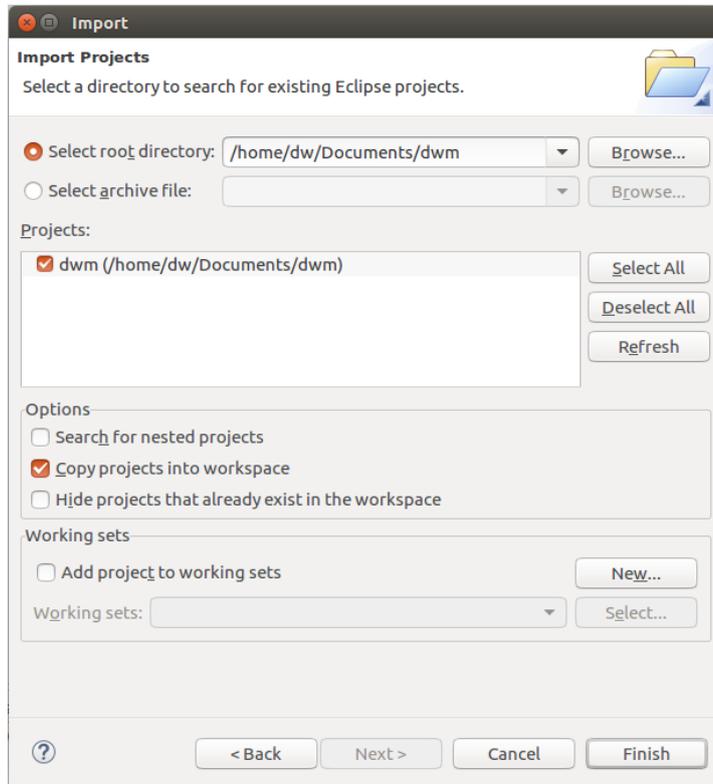
  e. Click "Finish".
4) Build.
  a. Click the dropdown list beside the 🔨 button. There are 3 options on the list.
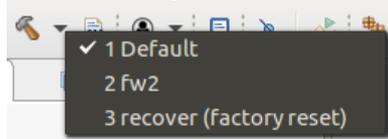
  b. Click option "2 fw2" to build the project.
  c. The build information is shown in Console view as on the figure below.
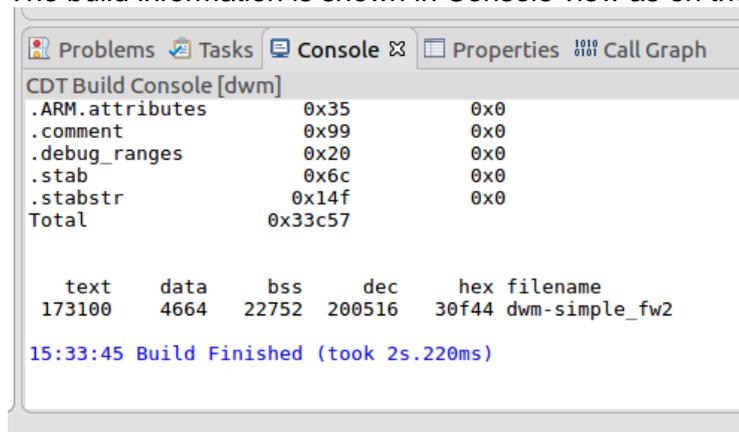
  d. If the dwm1001 module needs to be flashed with the factory image. Click option "3 recover (factory reset)". To do this, ensure the device is connected, see step 6) in Section 3.3.2 for more detail.
    Note: by doing this, the whole flash including the user configurations will be erased and reset.
5) Add user code.
    User customized code can be added in the application project: here an example of using the dwm_pos_get API call is given:

In Project Explorer view, expand project dwm, find dwm-simple.c in dwm/examples/dwm-simple/
a. Find function app_thread_entry, add in the local variable area:
   dwm_pos_t pos;
b. Find while(1) in function app_thread_entry and add in the brace:
   dwm_pos_get(&pos);
   printf("x=%ld, y=%ld, z=%ld, qf=%u \n", pos.x, pos.y, pos.z, pos.qf);
   printf("\t\t   time=%lu \n", dwm_systime_us_get());
   Note: printf will send the message to through UART interface when Shell mode is enabled.
c. Save.
d. Build the project and eliminate errors.

This change intends to read the position information in the device and print the message on the terminal. A system timer is added in the end of the message to indicate the message time.

The source file dwm/examples/dwm-simple/dwm-simple.c can be changed to add/modify functionalities. All available C code API functions are listed in header file dwm/include/dwm.h. More detailed information of the C code API is introduced in the DWM1001 API Guide [2].

6) Debug
   a. Connect the DWM1001 device. See step 6) in Section 3.3.2 for more detail.
   b. In Project Explorer view → Right click on dwm project → Debug As → Debug Configurations…
   c. Expand GDB OpenOCD Debugging and choose dwm_openocd.
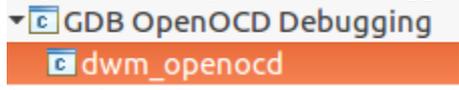
   d. Click "Debug". This will download the firmware onto the DWM1001 module and lead to Debug Perspective.
   e. Now the project can be debugged in Eclipse.

Note1: A few compilation options are provided in the dwm_user_start() function, with function names of dwm_XXXX_compile(), where XXXX is the component name. Disabling these functions can disable the corresponding components in the DWM1001 firmware.

Note2: It is possible to use breakpoints to debug the firmware. However the user has to be very carefull because the nRF52 softdevice interrupts are of highest priority, and if there is BLE activity its interrupts will conflict with user interrupt, thus the BLE should either be disabled or its interrupts masked. Disabling function dwm_ble_compile() can disable the BLE compilation so as to void BLE operations during debugging. The function can be re-enabled after debugging.

Note3: SWO debug printf is not supported on the DWM1001 DEV board.

4.3   UART applications example

The PANS library provides API functions through UART interface. The connection and simple examples are introduced here.

4.3.1   UART connection

The DWM1001 DEV board provides UART access through both the USB connector and the pins on the external connector. Both accesses are introduced here.

4.3.1.1 UART connection through COM port over USB

The UART connection can be setup simply through a USB data cable as shown in Figure 7. To find the device name of the DWM1001 DEV board in the Windows system:
1) Open Device and Printers,
2) Find the device J-Link:

Figure 7 J-Link Device in Windows

3) Double click the J-Link icon, go to Hardware tab and find the COM port with number as the device name (e.g. in Figure 8 below J-Link is device name is COM28).
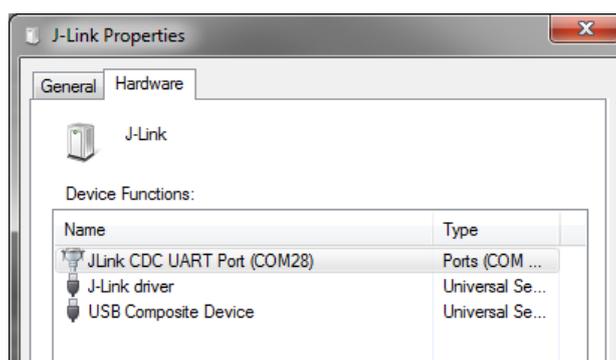
Figure 8 DWM1001 Device COM port over J-Link

In different Linux systems, the UART devices may show different names. In Linux VM, with connection shown in Figure 4 with the control of the device passed to Linux side as introduced in Figure 5, the device name is /dev/ttyACM0.

4.3.1.2 UART connection through external connector Tx and Rx pins

Other than using USB cable to connect, the external header pins provided on J10 of the DWM1001 DEV board also provides the UART interface. Table 1 shows the pins needed in the UART connection.

Table 1 UART pin connections

Pin to use in DWM1001 DEV		Pin to be connected to
Connector J10	Function	
Pin 6	GND	GND
Pin 8	RXD	TXD
Pin 10	TXD	RXD

For Raspberry Pi 3 using header pins connection, the device name is /dev/serial0.

The connection between the DWM1001 DEV board and a Raspberry Pi 3 (model B) is shown in Figure 9.

Figure 9 Connecting DWM1001 to Raspberry Pi 3 over header pins

Note: Pins on J10 of the DWM1001 DEV board are compatible with Raspberry Pi 3 connector J8 header pins 1-26.

4.3.2 UART examples

UART interface is accessible through two mode, the Shell mode and the Generic mode. Both Generic mode and Shell mode can be used to communicate with the DWM1001 module through the UART connection. The default mode of the DWM1001 UART is Generic mode. The two modes are transferrable:

Generic mode to Shell mode: presses "Enter" twice within one second, or input two bytes [0x0D, 0x0D] within one second.

Shell mode to Generic mode: input "quit" command.

For more information of the two UART API modes, please refer to DWM1001 API Guide [2].

4.3.2.1 UART Shell mode example

With the connection introduced in Figure 4, in VM Linux terminal, open the UART serial port:

> ➢ minicom -D /dev/ttyACM0

When seeing "Device or resource busy", try multiple times until it works.

When seeing "No such file or directory", check Section 3.3.1 step 6) and Figure 5.

If the connection over UART is successful, "Welcome to minicom" message will show on the terminal. Now hit "Enter" key twice within one second to enter UART shell mode. "dwm>" should present in the terminal when this is all done.

To run the UART Shell command for dwm_pos_get, type "apg" followed by "Enter" key. The position of the module in the whole DRTLS will be printed out, see Figure 10. Type "?" followed by "Enter" key to get help information in UART Shell mode. More information of the UART Shell commands is introduce in the DWM1001 API Guide [2].

```
dw@dw:~$ minicom -D /dev/ttyACM0

Welcome to minicom 2.7

OPTIONS: I18n
Compiled on Feb  7 2016, 13:37:32.
Port /dev/ttyACM0, 15:06:24

Press CTRL-A Z for help on special keys



 DWM1001 TWR Real Time Location System

 Copyright :  2016-2017 LEAPS and Decawave
 License   :  Please visit https://decawave.com/dwm1001_license
 Compiled  :  Jul 12 2017 18:00:01

 Help      :  ? or help

dwm> apg
x:121 y:50 z:251 qf:100
dwm>
```

Figure 10 Connect to DWM1001 device through UART shell

4.3.2.2 UART Generic mode example

A simple example to make use of the UART Generic API is given in the DWM1001 Host Api package [4]. The example runs on the Raspberry Pi platform:
1) Download the dwm1001_host_api package onto the Raspberry Pi 3 device. Navigate to folder examples/ex1_TWR_2Hosts/tag/
2) Use nano editor to edit Makefile:
    ➢ nano Makefile
3) Change the configuration parameter USE_INTERFACE to use UART interface:
    USE_INTERFACE = 0
4) Press "Ctrl + o" and "Enter" to save. Press "Ctrl + x" to exit nano editor.
5) Use "make" command to build the example:
    ➢ make
6) Run the executable:
    ➢ ./tag_cfg
7) Check log.txt file for the detail of UART data transmission.

```
pi@rpi-83:~/dwm1001_host_api/examples/ex1_TWR_2Hosts/tag $ ./tag_cfg
dwm_init(): dev0
Opening log file log.txt
        LMH_UARTRX_Init()...
        UART: Init start.
        UART: Init done.
Setting to tag: dev0.
dwm_cfg_tag_set(&cfg_tag): dev0.
Wait 2s for node to reset.
Comparing set vs. get: dev0.

Configuration succeeded.

Wait 1000 ms...
dwm_loc_get(&loc):
        [121,50,251,100]
Wait 1000 ms...
dwm_loc_get(&loc):
        [121,50,251,100]
Wait 1000 ms...
dwm_loc_get(&loc):
        [121,50,251,100]
```

Figure 11 Run simple UART example on Raspberry Pi 3

The simple UART Generic mode example project is designed specifically for Raspberry Pi platform. The source file examples/ex1_TWR_2Hosts/tag/tag_cfg.c can be changed to add/modify functionalities. All available UART API functions are listed in header file include\dwm_api.h. More detailed information of the UART Generic mode is introduced in the DWM1001 API Guide [2].

The code/makefile needs to be changed, to suit other platforms than Raspberry PI.

4.4 SPI applications example

The DWM1001 module provides APIs over the SPI interface. The connection and a simple example are introduced here.

4.4.1 SPI connection

To connect to the DWM1001 module over SPI, the SPI pins on external connector J10 on the DWM1001 DEV board can be used. Table 2 shows the pins needed in the SPI connection.

Table 2 SPI pin connections

Pin to use		Pin to be connected to
Pin number	Function	
Pin 19	MOSI	MOSI
Pin 21	MISO	MISO
Pin 23	SCLK	SCLK
Pin 25	GND	GND
Pin 24	CSN	CSN

The connection with Raspberry Pi 3 (model B) is shown in Figure 9.

Note: the connector J10 on the DWM1001 DEV board is compatible with Raspberry Pi 3 connector J8 header pins 1-26. Pin 4 from J10 provides 5V power from Raspberry Pi to the DWM1001 DEV board.

4.4.2 SPI example

A simple example to make use of the SPI API is given in the DWM1001 Host API package [4]. The example can run on the Raspberry Pi platform:
1) Download the dwm1001_host_api package onto the Raspberry Pi 3 device. Navigate to folder examples/ex1_TWR_2Hosts/tag/
2) Use nano editor to edit Makefile:
   ➢ nano Makefile
3) Change the configuration parameter USE_INTERFACE to use SPI interface:
   USE_INTERFACE = 1
4) Press "Ctrl + o" and "Enter" to save. Press "Ctrl + x" to exit nano editor.
5) Use "make" command to build the example:
   ➢ make
6) Run the executable:
   ➢ ./tag_cfg
7) Check log.txt file for the detail of SPI data transmission.

```
pi@rpi-83:~/dwm1001_host_api/examples/ex1_TWR_2Hosts/tag $ ./tag_cfg
dwm_init(): dev0
Opening log file log.txt
        LMH_SPIRX_Init(): SPI dev0...
        SPI0: spi mode: 0
        SPI0: bits per word: 8
        SPI0: max speed: 8000000 Hz (8000 KHz)
        SPI0: Resetting DWM1001 to SPI:IDLE
        LMH: LMH_SPIRX_Init for SPI dev0 done.
Setting to tag: dev0.
dwm_cfg_tag_set(&cfg_tag): dev0.
Wait 2s for node to reset.
Comparing set vs. get: dev0.

Configuration succeeded.

Wait 1000 ms...
dwm_loc_get(&loc):
        [121,50,251,100]
Wait 1000 ms...
dwm_loc_get(&loc):
        [121,50,251,100]
Wait 1000 ms...
dwm_loc_get(&loc):
        [121,50,251,100]
```

Figure 12 Run simple SPI example on Raspberry Pi 3

The simple SPI example project is designed specifically for Raspberry Pi platform. The source file examples/ex1_TWR_2Hosts/tag/tag_cfg.c can be changed to add/modify functionalities. All available SPI API functions are listed in header file include\dwm_api.h. More detailed information of the SPI API is introduced in the DWM1001 API Guide [2].

The code/makefile needs to be changed to suit other platforms than Raspberry PI.

5 REFERENCES

This document refers to the documents listed below. Note that References' format can be as the author chooses.

1. Nordic nRF52 series Softdevice introduction, available from www.nordicsemi.com
2. DW1000 Software API Guide, available from www.decawave.com
3. DWM1001 System Overview, available from www.decawave.com
4. DWM1001 Host API source code package available from www.decawave.com
5. Oracle VM VirtualBox, available from www.virtualbox.org
6. DWM1001 VM image, available from www.decawave.com
7. DWM1001 on-board source code package, available from www.decawave.com
8. DWM1001 Android application source package, available from www.decawave.com

6 DOCUMENT HISTORY

6.1 Revision History

Table 3: Document History

Revision	Date	Description
1.0	18-Dec-2017	Initial version.
1.1	11-Jan-2018	Editorial changes

7   CHANGE LOG

Revision 1.1

Page	Change Description
27	Remove unreleased documents from references
27	Repair url links for 2 references
10	Remove paragraph related to fig 2
10	Renumber references

8 ABOUT DECAWAVE

Decawave is a pioneering fabless semiconductor company whose flagship product, the DW1000, is a complete, single chip CMOS Ultra-Wideband IC based on the IEEE 802.15.4-2011 UWB standard. This device is the first in a family of parts that will operate at data rates of 110 kbps, 850 kbps and 6.8 Mbps.

The resulting silicon has a wide range of standards-based applications for both Real Time Location Systems (RTLS) and Ultra Low Power Wireless Transceivers in areas as diverse as manufacturing, healthcare, lighting, security, transport, inventory & supply chain management.

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