UM2063
User manual

STM32 TCPM Application

Introduction

This document describes the STM32 USB-PD (Power Delivery) Expansion Package for STM32Cube, referenced as X-CUBE-USB-PD.

To discover all our MCU based solutions for USB Type-C™ and Power Delivery technology please go to our landing page https://www.st.com/content/st_com/en/stm32-usb-c.html.

X-CUBE-USB-PD is a USB-IF certified Expansion Package and consists of libraries, drivers, sources, APIs, and application examples running on STM32F0 Series microcontrollers acting as USB Type-C™ port manager (TCPM).

The provided example helps to develop applications based on USB-PD DRP (Dual Role Power).

The core of the stack is delivered in library format while the open-source format device part offers a high level of flexibility to match the design considerations.

This Expansion Package supports one hardware implementation:

- Standardized TCPM/TCPC solution for any STM32 microcontroller
  - Ideal solution to upgrade legacy design based-on any STM32 with USB-C™
  - Lowest memory footprint and easy porting within the Cortex®-M series
  - USB-PD 2.0/3.0+PPS compliant, multi-port
  - Tested with TCPC controller from On-SEMI FUSB307B. Refer to *USB Type-C™ port manager (TCPM)/port controller (TCPC) evaluation board* (DB3623).

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1 Overview

This document describes how to use the USB-PD library supporting STM32 32-bit microcontrollers based on Arm®[(a)] cores, for regular use and to create a customized application.

It covers the following topics to ease the use of the library:

- USB-PD standard overview
- USB-PD library architecture
- USB-PD stack usage description

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1.1 Acronyms and abbreviations

Table 1. List of acronyms

Term	Meaning
API	Application programming interface
CAD	Cable detection module
CC	Configuration channel
DFP	Downstream facing port
DPM	Device policy manager
DRP	Dual role port
FW	Firmware
HW	Hardware
PD	Power delivery
PE	Policy engine
PRL	Protocol layer
TCPC	USB Type-C™ port controller
TCPCi	USB Type-C™ port controller interface
TCPM	USB Type-C™ port manager
UFP	Upstream facing port
USB	Universal serial bus
VDM	Vendor defined messages

a. Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

1.2 References

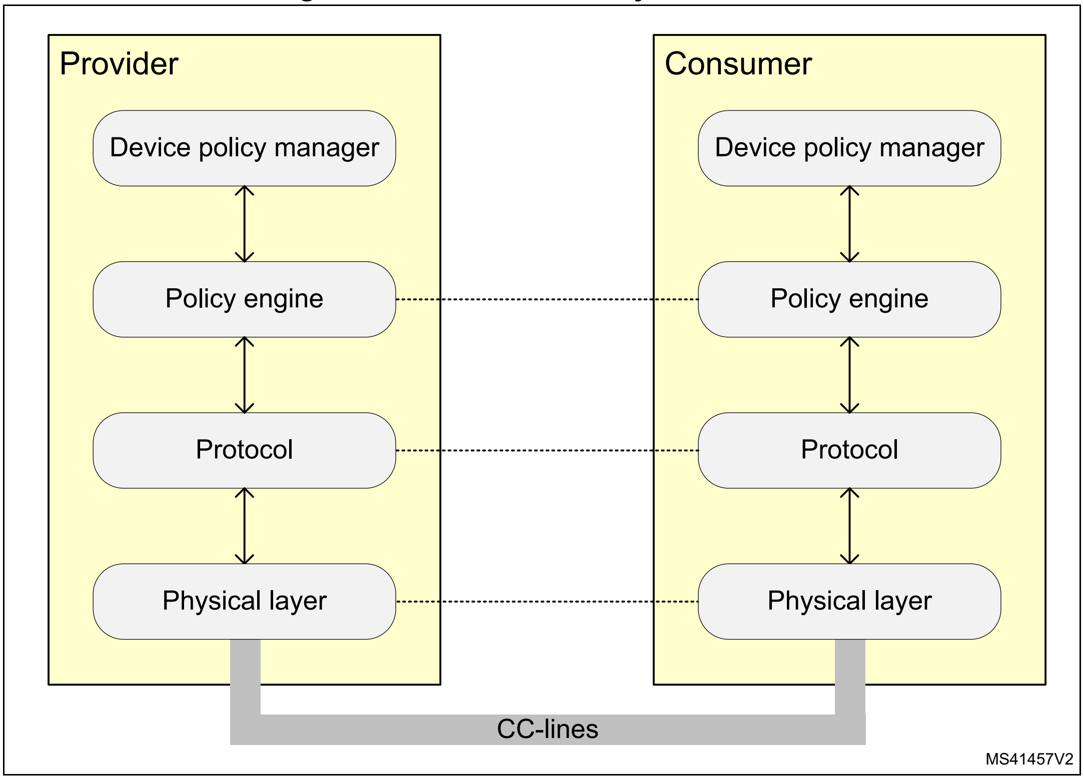
- Universal Serial Bus Power Delivery Specification, Revision 3.0, Version 2.0, August 29, 2019
- Universal Serial Bus Type-C™ Cable and Connector Specification 2.0, August 2019
- Universal Serial Bus Type-C™ Port Controller Interface Specification, Revision 1.0, Version 1.2, November 2016
- User manual *Managing USB power delivery systems with STM32 microcontrollers* (UM2552)
- Application note *USB Type-C™ Power Delivery using STM32xx Series MCUs and STM32xxx Series MPUs* (AN5225)
- ST wiki USBPD overview: https://wiki.st.com/stm32mcu/wiki/USB_Power_Delivery_overview
- STM32CubeMonitor-UCDPD: https://www.st.com/en/product/stm32cubemonucpd

2 USB-C™ PD architecture

2.1 Architecture overview

The USB Power Delivery specification document defines the communicating layers of a PD device (either provider or consumer) as shown in *Figure 1*.

Figure 1. USB Power Delivery architecture



A PD3.0-capable device is assumed to be made up of at least one port, which can

- sink power (a consumer), source power (a provider), or toggle between the two roles (dual role power)
- optionally communicate via USB
- communicate using SOP Packets
- optionally communicate using SOP Prime packets.

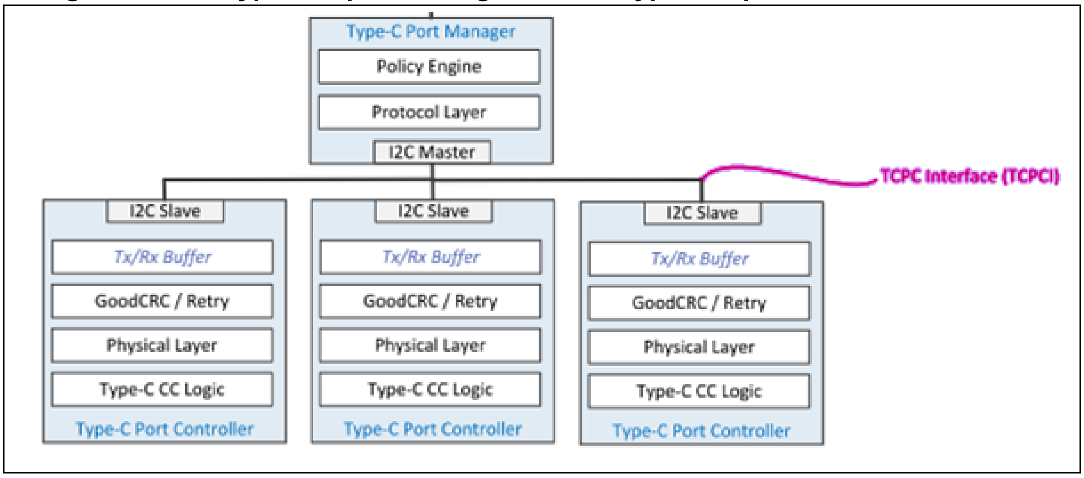
Where USB products support USB Power Delivery protocols a USB DFP is initially a Source and a USB UFP is initially a Sink, although USB-PD enables the Source/Sink and the DFP/UFP roles to be swapped.

Note: There is only one Source port and one Sink port in each PD communication between port partners.

2.2 Specific case of TCPM/TCPC architecture

Implementation of USB-PD function may also be achieved in a TCPM/TCPC architecture, with a standardized interface between USB Type-C™ port manager (TCPM) and a simple USB Type-C™ port controller (TCPC) with the goal of easing USB Type-C™ Power Delivery implementations.

Figure 2. USB Type-C™ port manager to USB Type-C™ port controller interface



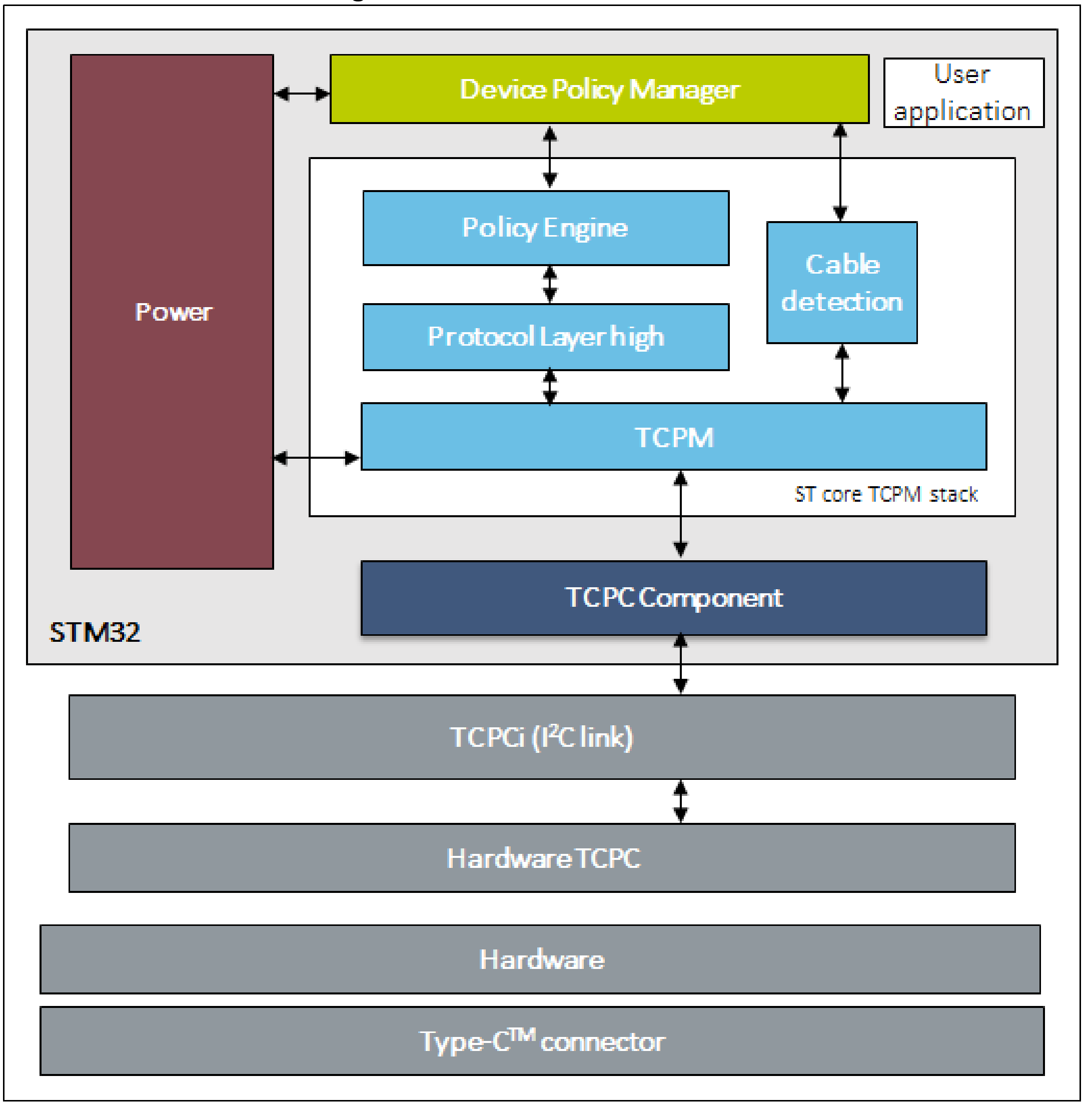
TCPC interface (TCPCi) is using an I^2C link and an alert pin. USB Type-C™ port controller interface Specification (TCPCi) defines the interface between the TCPM and the TCPC(s). In this architecture, one TCPM may be used to drive multiple TCPCs.

Protocol (PRL) functionalities are shared between TCPM and TCPC. TCPC must manage:

- GoodCRC management
- Retransmission

ST firmware architecture is described in *Figure 3*:

Figure 3. ST firmware architecture



- Device Policy Manager (DPM)
  DPM's role is to manage all the ports present in the application and to share the power between them according to the capability of the connected port partners. Once the negotiation of power has ended, an explicit contract is concluded between them.
  DPM can manage VDM exchanges, to manage the alternate modes, only once an explicit contract is established. This layer is the high level of the USB C power stack and the place where the user defines the power strategy of its application.
- Policy Engine (PE) layer
  The Policy Engine (PE) role is to drive the message sequences according to the sent message and to its expected response. It allows negotiating power, establishing an Explicit Contract for the power exchange.
  The acceptance or the refusal of a request depends on the response of the DPM towards a specific power profile.
  The PE also handles the Vendor Defined Messages flow, allowing to discover, enter or

exit specified modes according to those supported by both provider and consumer sides.

- Protocol layer high (PRL layer high)
  This layer's role is to construct, transmit, and receive messages from/to TCPC layers to/from the PE layer.
  It interacts with the TCPM layer to transmit messages to TCPC through the TCPCi interface.
- USB Type-C™ protocol management (TCPM)
  This layer must handle messages exchanged between PRL and TCPC layers. It means the management of alerts raised by TCPC, wrap communications, and others.
- USB Type-C™ protocol controller (TCPC) component
  This layer is used to define all the registers accesses linked to TCPC component used for USB Type-C™.
- USB Type-C™ protocol controller interface (TCPCi)
  This layer manages all the I^2C transactions between TCPM and TCPC and also interruptions linked to alerts.
- TCPC hardware
  This layer is responsible for sending and receiving messages across the CC wires.
  The TCPC hardware implements the entire USB-PD PHY layer with BMC encoding.
  The TCPC implements a portion of the protocol layer transmission state diagram.
  – CRCReceiveTimer
  – RetryCounter
  – Messages that are received are passed to the TCPM via I^2C
  – BIST handling

Note: For more information about the USB Power Delivery protocol, refer to the official specification document mentioned in Section 1.2.

3 USB-PD ST application setup

The USB-C™ Power Delivery library is provided in binary format, comes on top of the STM32Cube HAL driver, and offers all the APIs required to develop a USB-PD application.

This section describes the USB-PD library middleware integration and illustrates how users can develop their own power-delivery applications using this library.

The USB-PD library is developed following the Universal Serial Bus Power Delivery Specification and Universal Serial Bus Type-C™ Cable and Connector Specification, refer to *Section 1.2*, and this library is officially certified.

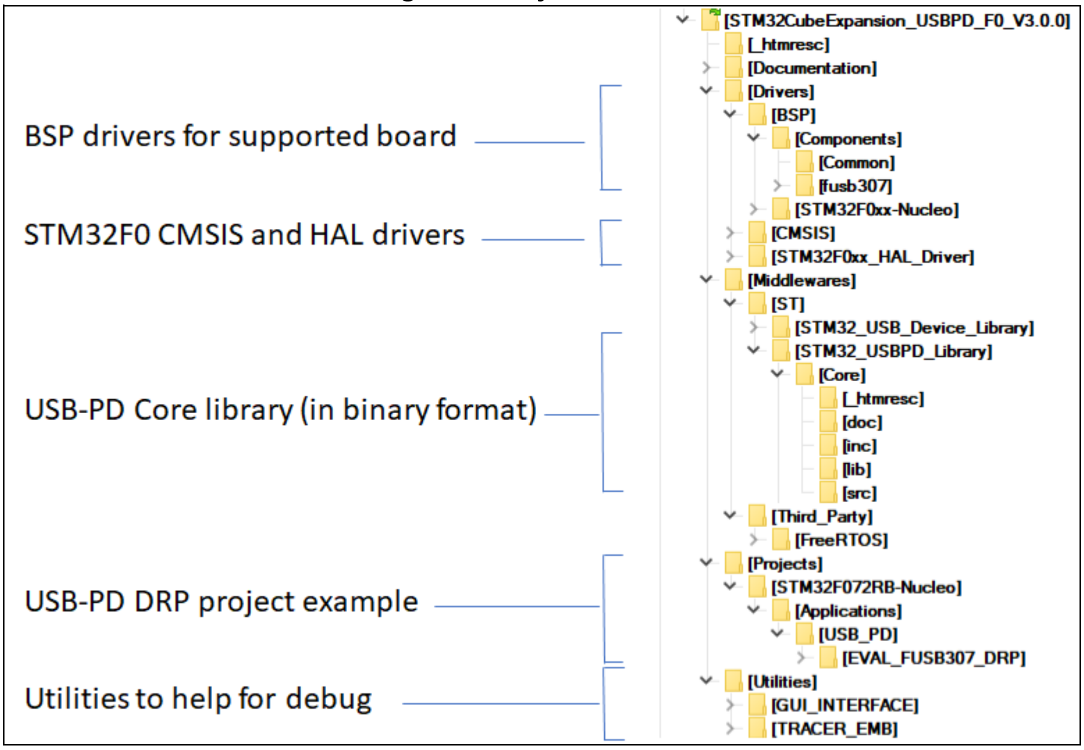
The STM32 USB-PD package contains:

- The USB-PD core stack and the device drivers
- An example with USB-PD DRP (TCPM/TCPC architecture) with ON Semiconductor FUSB307 evaluation board

More details on the stack library can be found in the user manual regarding the management of USB Power Delivery systems with STM32 MCUs and the wiki. For both links, refer to *Section 1.2*.

4 Examples description

Figure 4. Project structure



4.1 USB-PD DRP (TCPM/TCPC architecture)

This project implements a USB-PD DRP application, suitable for the ON Semiconductor FUSB307 evaluation board, based on the use of USB-PD libraries delivered in the X-CUBE-USB-PD Expansion Package, and highlighting the TCPM/TCPC architecture.

4.1.1 Example setup

The USB-PD TCPM/TCPC designed for FUSB307 evaluation board application can be found under Projects\STM32F072RB-Nucleo\Applications\USB_PD\EVAL_FUSB307_DRP

This application provides an example of USB Power Delivery implementation based on TCPM/TCPC architecture. The application and USB-PD core stack are located on the TCPM side and are running on the STM32F0xx Nucleo device on the ON Semiconductor FUSB307 board. The application is driving the TCPC controller through the I^2C link.

4.1.2 Application description

When the application starts, USB-PD has the capability of operating as either a Source or Sink.

When connecting to a USB-PD device (source or sink), the application must detect the type of connected device, and adopt a corresponding suitable role, in order to trigger the power negotiation:

- User must plug the USB-C™ cable on the dedicated connector.
- When the STM32 MCU side behaves as a Consumer (Sink mode), i.e. when connected to a Source device, it waits for Power Capabilities message from the attached provider. When a Source Capabilities message is received, the STM32 starts the evaluation of the received capabilities and check if one of the received power objects can meet its power requirement. The STM32 sends the Request message to request the new power level from the offered Source Capabilities. Once the PS_RDY message is received, the Explicit Contract is established.
- When the STM32 MCU side behaves as a Provider (Source mode), i.e. when connected to a Sink device, it exchanges Power profiles with the connected device and waits for Power Request message from the attached consumer. If the requested power can be met, the STM32 MCU sends the Accept message followed by the PS_RDY message. Explicit Contract is then considered as established.

4.1.3 Library initialization

Refer to section 3.3 Application initialization of the user manual *Managing USB power delivery systems with STM32 microcontrollers* (UM2552).

4.1.4 TCPM API description

For a complete description of the USB-PD core stack callbacks to be implemented on the DPM user side, refer to the CHM file provided in the *Documentation* directory of the X-CUBE-USB-PD Expansion Package (*STM32F072xB_USBPD_CORE_RELEASE_User_Manual.chm*), in particular to `USBPD_PE_Callbacks Struct` reference description. For a complete description of the USBPD core TCPM stack callbacks to be implemented on the TCPC component side, refer to the CHM file provided in the *Documentation* directory of the X-CUBE-USB-PD Expansion Package (*STM32F072xB_USBPD_CORE_TCPM_RELEASE* user manual), in particular to `TCPC_DrvTypeDef` Reference description

5 Memory footprint of the EVAL_FUSB307_DRP example

The values in *Table 2* are calculated according to the following configuration:

- Compiler: IAR™ Embedded Workbench® for Arm®, Version 8.32.3
- Optimization: high size
- MCU: STM32F072RB
- ON-FUSB3-STM32 board

Table 2. USB-PD - Dual role port memory footprint (in bytes)

Software	Flash memory	RAM	Description
GUI	7904	700	Responder for STM32CubeMonitor-UCDPD (STM32CubeMonUCPD) graphical user interface
Application	5286	352	Application
USB-PD library	25592	72	PD3 Config1 stack
DRV	7334	364	TCPCi drivers for FUSB305
HAL	3912	40	STM32 HAL/LL drivers (Like Flash, I^2C, USART for debugging)
Debug	1550	1044	For Tracer debugging (STM32CubeMonitor-UCPD)
FreeRTOS™	4332	7028	FreeRTOS™ allocation and services
sideLib	2654	2904	IAR™ libraries
Device	960	76	For *usbpd_pwr_if.c*
Total	59554	12580	-

6 Frequently asked questions (FAQs)

How can I get the STM32 USB-PD library?

The library is provided for free download in a binary format, from *www.st.com*. The general application note *USB Type-C™ Power Delivery using STM32xx Series MCUs and STM32xxx Series MPUs* (AN5225) describes how to do power delivery with the STM32. This firmware package for X-CUBE-USB-PD is located also on the gitub server: https://github.com/STMicroelectronics/x-cube-usb-pd.

I want to use only the USB-C™ feature (cable detachment attachment and cable orientation). Is this possible?

Yes, this is possible since the CAD (Cable attachment and detachment) module and the PD communication are driven by two separate processes. You can call only the CAD process to ensure cable detection.

Does the X-CUBE-USB-PD Expansion Package work on platforms different from STM32F0?

The core stack is device-independent. The STM32F0 and STM32F4 are supported on the device part in this delivery.

More information can be found in https://wiki.st.com/stm32mcu/wiki/USB_Power_Delivery_overview

7 Revision history

Table 3. Document revision history

Date	Revision	Changes
08-Jun-2016	1	Initial release.
23-Jan-2017	2	Updated *Section 1.2: References*, *Section 3.1: Overview*, *Section 3.2: Features*, *Section 3.3: Library architecture*, *Section 3.4: Hardware related components (for P-NUCLEO-USB001)*, *Section 4: USB-PD library programming guidelines*, *Section 4.2: Library initialization*, *Section 4.3: USB-PD core stack library functions*, *Section 4.4: USB-PD core stack*, *Section 6.1: Hardware description*, *Section 6.2: USB-PD provider*, *Section 6.5: USB-PD consumer*, *Section 6.8: USB-PD consumer DRP* and *Section 8: Frequently asked questions (FAQs)*. Added *Section 6.3: USB-PD provider (with CLI support)*, *Section 6.4: USB-PD provider (with VDM support)*, *Section 6.6: USB-PD consumer (with CLI support)*, *Section 6.7: USB-PD consumer (with VDM support)* and *Section 6.9: USB-PD Dual Port*. Updated *Table 1: List of acronyms*, *Table 2: Use of different IPs*, *Table 3: GPIOs used by Port0*, *Table 4: GPIOs used by Port1*, *Table 6: DPM files*, *Table 7: USB-PD user functions*, *Table 8: USB-C™ PD callbacks*, *Table 9: USB-PD - Provider memory footprint (in Bytes)*, *Table 10: USB-PD - Consumer memory footprint* and *Table 11: USB-PD - Dual role port memory footprint*. Updated *Figure 6: Project files*.
09-May-2018	3	Updated *Introduction*, *Section 1.2: References*, *Section 2.1: Architecture overview*, *Section 3.1: Overview*, *Section 3.2: Features*, *Section 3.3: Library architecture*, *Section 3.4: Hardware related components (for P-NUCLEO-USB001)*, *Section 4: USB-PD library programming guidelines*, *Section 4.2: Library initialization*, *Section 4.4: USB-PD core stack*, *Section 6.5.1: Example setup*, *Section 6.9.1: Example setup*, *Section 7: Memory footprint* and *Section 8: Frequently asked questions (FAQs)*. Added *Section 4.5: USB-PD device components*. Updated *Figure 1: USB power delivery architecture*, *Figure 6: Project files* and *Figure 7: USB-PD stack architecture (for P-NUCLEO-USB001)*. Updated *Table 6: USB-PD - Provider memory footprint (in Bytes)*, *Table 7: USB-PD - Consumer memory footprint (in Bytes)* and *Table 8: USB-PD - Dual role port memory footprint (in Bytes)*. Removed former *Table 6: DPM files*, *Table 7: USB-PD user functions* and *Table 8: USB-C™ PD callbacks*.
30-May-2018	4	Updated *Introduction* Added *Chapter 2.2: Specific case of TCPM/TCPC architecture*, *Chapter 4.1: Description of available configurations*, *Chapter 5: Atomic message sequencing* and *Chapter 6.10: USB-PD DRP (TCPM/TCPC architecture)*

Table 3. Document revision history

Date	Revision	Changes
10-Apr-2020	5	Updated *Introduction* Former section 3 moved to *Section 4.1.4: TCPM API description* Removed P-NUCLEO-USB001 and P-NUCLEO-USB002. The first is obsolete, and the second is download-able from another page.
16-Jun-2020	6	Updated: – *Figure 4: Project structure* simplified, – *Section 4.1.3: Library initialization* referring to the corresponding UM2552 section.