# Compare Results

| Old File: | | New File: |
|---|---|---|
| **USB_PD_R3_1 V1.8 2023-04_Ch2.pdf** | versus | **USB_PD_R3_2 V1.0 2023-10_Ch 2.pdf** |
| **20 pages (831 KB)** | | **25 pages (842 KB)** |
| 13/10/2023 19:35:22 | | 31/10/2023 18:08:09 |

**Total Changes**

397

Text only comparison

**Content**

| | |
|---|---|
| 239 | Replacements |
| 87 | Insertions |
| 71 | Deletions |

**Styling and Annotations**

| | |
|---|---|
| 0 | Styling |
| 0 | Annotations |

Go to First Change (page 1)

# 2. Overview

This section contains no ***Normative*** requirements.

## 2.1 Introduction

USB Power Delivery (PD) defines the mechanisms for pairs of directly Attached ports (also referred to as Port Partners or Port Pairs) to negotiate Voltage, current and/or direction of power flow over the USB cable. It uses the USB Type-C® connector's CC wire as the communications channel. The PD mechanisms operate independently of and supersede other USB methods defined in the base specs, BC1.2 spec and the USB Type-C spec.

USB Power Delivery also defines sideband mechanisms used for configuration management of USB Type-C devices and cables. Using Structured Vendor Defined Messages (Structured VDMs), PD facilitates discovery of device and cables features and performance. Structured VDMs are also used to enter/exit operational modes, either USB-based (e.g., USB4) or USB Type-C Alternate Modes. Alternate Modes are associated with Standard Vendor IDs (SVIDs) and can be either standard (e.g., DisplayPort Alternate Mode) or proprietary (e.g., Intel Thunderbolt™ 3).

### 2.1.1 Power Delivery Source Operational Contracts

A PD Source will be in one of three Contracts:

- Default Contract which it enters immediately following a connect where the Source provides 5V and advertises the amount of current it can deliver using the $R_p$ value as defined in ***[USB Type-C 2.3]***. A Source in a Default Contract will remain in this Contract until t:he Sink is disconnected or the Source and Sink negotiate and enter an Explicit Contract.
- Implicit Contract which immediately follows a PR Swap or FR Swap and is transitory. The PD Source provides 5V and advertises the amount of current it can deliver using the $R_p$ value as defined in ***[USB Type-C 2.3]***. A Source in an Implicit Contract will immediately negotiate with the Sink and enter an Explicit Contract.
- Explicit Contract is the state of the Source after any PD power negotiation consisting of the Source sending a ***Source_Capabilities*** Message, the Sink responding with a ***Request*** Message, the Source acknowledging the request with an ***Accept*** Message and finally the Source sends a ***PS_RDY*** Message when the Source is ready to deliver the requested power. This is the normal operational state for PD. A Source in an Explicit Contract will remain in an Explicit Contract during and after a renegotiation of its Contract and will exit the Explicit Contract when:
  - Disconnected from the Sink where it will restart in Default state when reconnected to the Sink.
  - Following a Hard Reset where it will restart as if it were disconnected then reconnected to the Sink.
  - Following a PR Swap or FR Swap where it will enter an Implicit Contract.

### 2.1.2 Power Delivery Contracts

Contracts negotiated using the USB Power Delivery Specification supersede any and all previous power contracts established whether from standard ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 2.3]*** or ***[USBBC 1.2]*** mechanisms. While operating in Power Delivery Mode there will be a Contract in place (either Explicit or Implicit) that determines the power level available and the direction of that power. The Port Pair will remain in Power Delivery Mode until the Port Pair is Detached, there is a Hard Reset, or the Source removes power except as part of the Power Role Swap or Fast Role Swap processes.

Note ***[USB4]*** does not define a default power, rather relies on a USB PD power contract. When first attached the ***[USB4]*** device operates in ***[USB 3.2]*** mode which is its USB Default Operation.

An Explicit Contract is negotiated by the process of the Source sending a set of Capabilities, from which the Sink is required to request a particular capability and then the Source accepting this request.

An Implicit Contract is the specified level of power allowed in particular states (i.e., during and after a Power Role Swap or Fast Role Swap). Implicit Contracts are temporary; Port Pairs are required to immediately negotiate an Explicit Contract.

Each Provider has a Local Policy, governing power allocation to its Ports. Sinks also have their own Local Policy governing how they draw power. A System Policy can be enacted over USB that allows modification to these local policies and hence management of overall power allocation in the system.

When PD Capable devices are Attached to each other, the DFPs and UFPs initially default to standard USB Default Operation. The DFP supplies ***vSafe5V*** and the UFP draws current in accordance with the rules defined by ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 2.3]*** or ***[USBBC 1.2]*** specifications. After Power Delivery negotiation has taken place power can be supplied at higher, or lower, Voltages and higher currents than defined in these specifications. It is also possible to:

- Do a Power Role Swap or Fast Role Swap to exchange the power supply roles such that the DFP receives power and the UFP supplies power.
- Do a Data Role Swap such that the DFP becomes the UFP and vice-versa.
- Do a Vconn Swap to change the Port supplying VCONN to the cable.
- Enter into EPR operation.
- Enter into ***[USB4]*** operation.
- Enter into alternate modes.
- Send vendor defined Messages.

Prior to an Explicit Contract only the Source Port, which is also the VCONN Source, can communicate with the Attached cable assembly. This is important where 5A and EPR capability are marked as well as other details of the cable assembly such as the supported speed.

Cable discovery, determining whether the cable can communicate, can occur on initial Attachment of a Port Pair before an Explicit Contract has been established. It is also possible to carry out cable discovery after a Power Role Swap or Fast Role Swap prior to re-establishing an Explicit Contract, where the UFP is the Source, and an Implicit Contract is in place. Cable discovery can be carried out after an Explicit Contract has been established, if the Cable has not yet been discovered.

### 2.1.3 Other Uses for Power Delivery

Once an Explicit Contract is in place, PD can be used to manage the ports and cables for non-power related functionality.

PD is used to enter the ***[USB4]*** mode of operation. Ports and cables may support functionality beyond power. For example, a cable may have active components that require VCONN power or a port/cable may support a video display mode such as DisplayPort. PD defines an infrastructure to discover these additional capabilities and modes that include:

- Discovering a port or cable's capabilities.
- Discovery of the SVIDs a port or cable supports.
- Discovery of the Modes a port or cable supports.
- Entry into a Mode supported by the port and/or cable.

- Exiting Modes supported by the port and/or cable.

## 2.2 Compatibility with Revision 2.0

Revision 3.2 of the USB Power Delivery specification is designed to be fully interoperable with *[USBPD 2.0]* systems using BMC signaling over the *[USB Type-C 2.3]* connector and to be compatible with Revision 2.0 hardware.

This specification mandates that all Revision 3.2 systems fully support Revision 2.0 operation. They must discover the supported Revision used by their Port Partner and any connected Cable Plugs and revert to operation using the lowest common Revision number (see *Section 6.2.1.1.5, "Specification Revision"*).

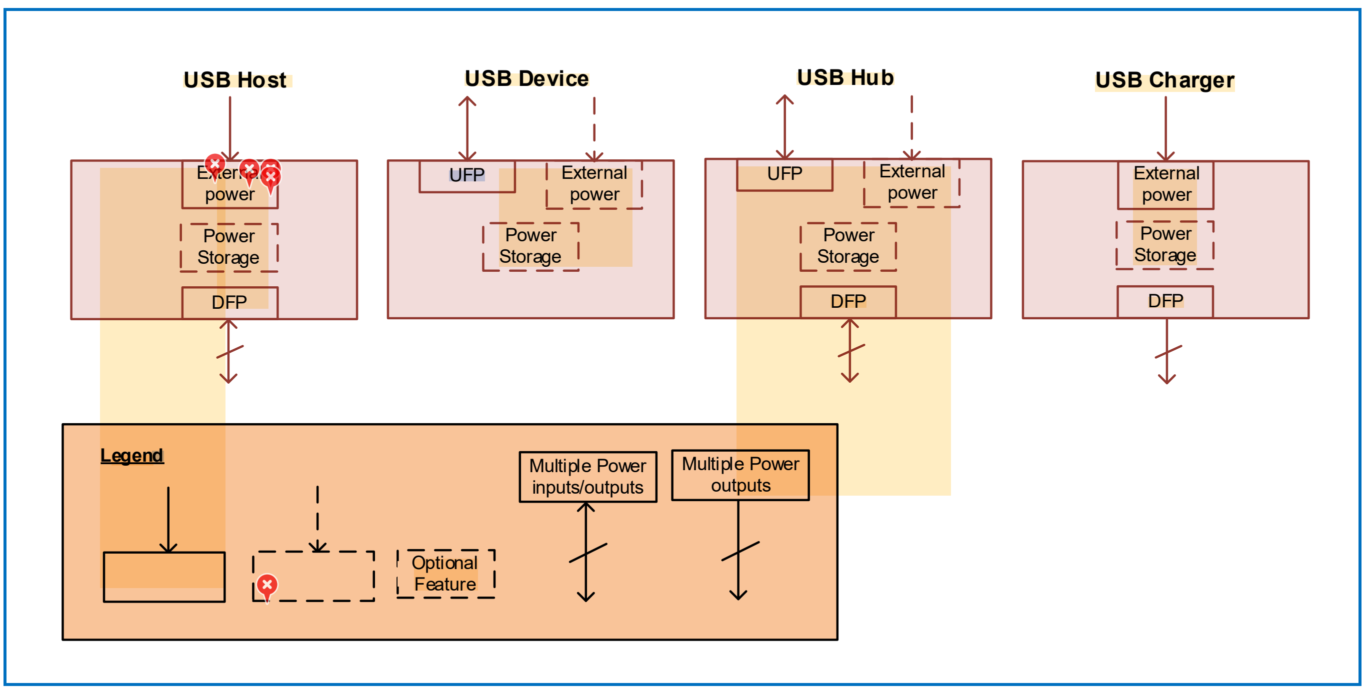
This specification defines Extended Messages containing data of up to 260 bytes (see *Section 6.2.1.2, "Extended Message Header"*). These Messages can be larger than expected by existing PHY HW. To accommodate Revision 2.0 based systems a Chunking mechanism is mandated such that Messages are limited to Revision 2.0 sizes unless it is discovered that both systems support the longer Message lengths.

This specification includes changes to the Vendor Defined Objects (VDO) used in the discovery of passive/active marked cables and Alternate Mode Adapters (AMA) (see *Section 6.4.4.2, "Structured VDM"*). To enable systems to determine which VDO format is being used the Structured Vendor Defined Message (SVDM) version number has been incremented to 2.x. Version numbers have also been incorporated into the VDOs themselves to facilitate future changes if these become necessary.

## 2.3 USB Power Delivery Capable Devices

Some examples of USB Power Delivery capable devices can be seen in *Figure 2-1 "Logical Structure of USB Power Delivery Capable Devices"* (a Host, a Device, a Hub, and a Charger). These are given for reference only and are not intended to limit the possible configurations of products that can be built using this specification.

**Figure 2-1 "Logical Structure of USB Power Delivery Capable Devices"**



Each USB Power Delivery capable device is assumed to be made up of at least one Port. Providers are assumed to have a Source and Consumers a Sink. Each device contains one, or more, of the following components:

- UFPs that:
  - Sink Power.
  - Communicate using SOP Packets.
  - Optionally Communicate using SOP* Packets.
  - Optionally source power (a Dual-Role Power Device).
  - Optionally communicate via USB.
  - Optionally support Alternate Modes.
- DFPs that:
  - Source Power
  - Communicate using SOP Packets.
  - Optionally Communicate using SOP* Packets.
  - Optionally Sink power (a Dual-Role Power Device).
  - Optionally communicate via USB.
  - Optionally support Alternate Modes.
- A Source that can be:
  - An externally powered source (e.g., AC powered).
  - Power Storage (e.g., Battery/Power Bank).
  - Derived from another Port (e.g., bus-powered Hub).
- A Sink that can be:
  - Power Storage (e.g., a Battery/Power Bank).
  - Used to power internal functions.
  - Used to power devices Attached to other devices (e.g., a bus-powered Hub).
- A VCONN Source that:
  - Can be either Port Partner, either the DFP/UFP or Source/Sink.
  - Powers the Cable Plug(s).
  - Powers VPDs (VCONN Powered Devices).
  - Is the only Port allowed to talk to the Cable Plug(s) at any given time.

## 2.4 SOP* Communication

### 2.4.1 Introduction

The Start of Packet (or SOP) is used as an addressing scheme to identify whether the Communications were intended for one of the Port Partners (SOP Communication) or one of the Cable Plugs (SOP'/SOP'' Communication). SOP/SOP' and SOP'' are collectively referred to as SOP*. All SOP* Communications take place over a single wire (CC). The term Cable Plug in the SOP'/SOP'' Communication case is used to represent a logical entity in the cable which is capable of PD Communication, and which might or might not be physically located in the plug.

Note there are there are other SOPs defined for special operation such as debug which are not discussed here.

The following sections describe how this addressing scheme operates for Port to Port and Port to Cable Plug Communication.

### 2.4.2 SOP* Collision Avoidance

For all SOP* the Source co-ordinates communication to avoid bus collisions by allowing the Sink to initiate messaging when it does not need to communicate itself. Once an Explicit Contract is in place, the Source manipulates its $R_p$ value (3A) to indicate to the Sink that it can initiate a message sequence. This sequence can be communication with the Source or with one of the Cable Plugs. As soon as the Source itself needs to initiate a message sequence, it will manipulate its $R_p$ value (1.5A) to indicate this to the Sink. The Source then waits for any outstanding Sink SOP* Communication to complete before initiating a message sequence itself. In all cases, the Port initiating a message waits for CC to be idle before putting the message on CC.

### 2.4.3 SOP Communication

SOP Communication is used for Port-to-Port communication between the Source and the Sink. SOP Communication is recognized by both Port Partners but not by any intervening Cable Plugs. SOP Communication takes priority over other SOP* Communications since it is critical to complete power related operations as soon as possible.

### 2.4.4 SOP'/SOP'' Communication with Cable Plugs

SOP' Communication is recognized by electronics in one Cable Plug (see ***[USB Type-C 2.3]***). SOP'' Communication can also be supported when SOP' Communication is also supported. SOP' and SOP'' assignment in the cable assembly is fixed and does not change dynamically.

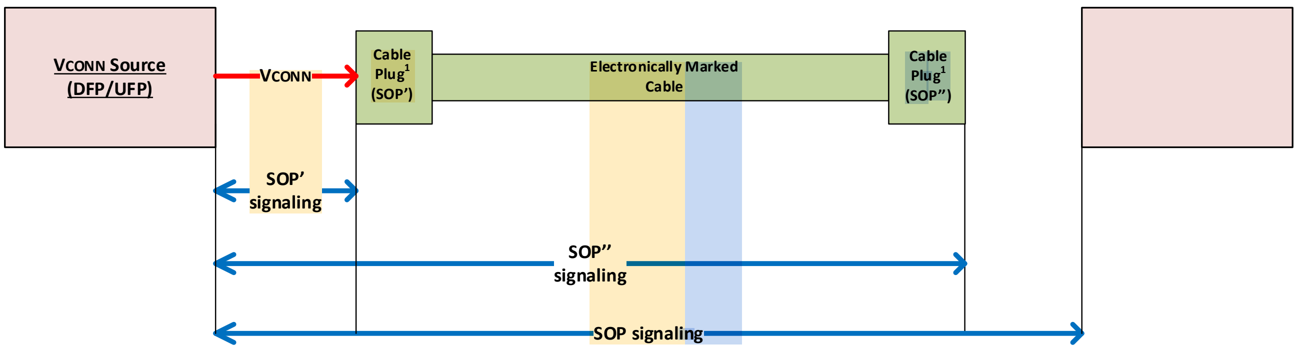
SOP Communication between the Port Partners is not recognized by the Cable Plug. ***Figure 2-2 "Example SOP' Communication between Vconn Source and Cable Plug(s)"*** outlines the usage of SOP* Communications between a VCONN Source (DFP/UFP) and the Cable Plugs.

Since all SOP* Communications take place over a single wire (CC), the SOP* Communication periods must be coordinated to prevent important communication from being blocked. For a product which does not recognize SOP/SOP' or SOP'' Packets, this will look like a non-idle channel, leading to missed packets and retries. Communications between the Port Partners take precedence meaning that communications with the Cable Plug can be interrupted but will not lead to a Soft or Hard Reset.

When a Default or Implicit Contract is in place (e.g., at startup, after a Power Role Swap or Fast Role Swap) only the Source port that is supplying VCONN is allowed to send packets to a Cable Plug (SOP') and is allowed to respond to packets from the Cable Plug (SOP') with a ***GoodCRC*** Message in order to discover the Cable Plug's characteristics (see ***Figure 2-2 "Example SOP' Communication between Vconn Source and Cable Plug(s)"***). During this phase, all communication with the Cable Plug is initiated and controlled by the Source which acts to prevent conflicts between SOP and SOP' Packets. The Sink does not communicate with the Cable Plug and ***Discards*** any SOP' Packets received.

When an Explicit Contract is in place, only the VCONN Source (either the DFP or the UFP) can communicate with the Cable Plug(s) using SOP'/SOP'' Packets (see *Figure 2-2 ""Example SOP' Communication between Vconn Source and Cable Plug(s)"*). During this phase, all communication with the Cable Plug is initiated and controlled by the VCONN Source which acts to prevent conflicts between SOP* Packets. The Port that is not the VCONN Source is not allowed to communicate with the Cable Plug and does not recognize any SOP'/SOP'' Packets received. Only the DFP, when acting as a VCONN Source, is allowed to send SOP* to control the entry and exiting of Modes and to manage Modal Operation.

**Figure 2-2 "Example SOP' Communication between VCONN Source and Cable Plug(s)"**




1) Cable Plug can be physically Attached to either the DFP or UFP.

## 2.5 Operational Overview

A USB Power Delivery Port supplying power is known as a Source and a Port consuming power is known as a Sink. There is only one Source Port and one Sink Port in each PD connection between the Port Partners. At Attach the Source Port (the Port with $R_p$ asserted see ***[USB Type-C 2.3]***) is also the DFP and VCONN Source. At Attach the Sink Port (the Port with $R_d$ asserted) is also the UFP and is not the VCONN Source.

The original USB PD specification allowed Sources to deliver up to 100W. This classic mode of operation is referred to as the Standard Power Range (SPR). The initial Explicit Contract, the first contract after the Default or Implicit contract, is always an SPR contract. There is an optional higher power mode referred to as the Extended Power Range (EPR) where the Source is allowed to deliver up to 240W. The EPR mode can only be entered from the SPR mode. The entry process is designed to prevent accidental entry into this higher power mode. It can be entered only when an Explicit SPR Contract is in place and both the Source and Sink Ports as well as the Cable support EPR.

The Source/Sink roles, DFP/UFP roles and VCONN Source role can all subsequently be swapped orthogonally to each other. A Port that supports both Source and Sink roles is called a Dual-Role Power Port (DRP). A Port that supports both DFP and UFP roles is called a Dual-Role Data Port (DRD).

When USB Communications Capability is supported in the DFP role then the Port will also be able to act as a USB Host. Similarly, when USB Communications Capability is supported in the UFP role then the Port will also be able to act as a USB Device.

The following sections describe the high-level operation of ports taking on the roles of DFP, UFP, Source and Sink.

For details of how PD maps to USB states in a PDUSB Device see *Section 9.1.2 "Mapping to USB Device States"*.

### 2.5.1 Source Operation

The Source operates differently depending on its Attachment status:

- At Attach (no PD Connection or Contract):
  - For a Source-only Port the Source detects Sink Attachment.
  - For a DRP that toggles between Source and Sink operation, the Port becomes a Source Port on Attachment of a Sink
  - The Source then supplies ***vSafe5V***.
- Before PD Connection (no PD Connection or PD Contract):
  - Prior to sending ***Source_Capabilities*** Messages the Source can detect the type of cabling Attached and can alter its Advertised capabilities depending on the type of cable detected:
    - The default capability of a USB Type-C® cable is 3A.
    - The Source can attempt to communicate with one of the Cable Plugs using SOP' Packets. If the Cable Plug responds, then communication takes place to discover the cable's capabilities (e.g., 5A capable).
  - The Source periodically Advertises its capabilities by sending ***Source_Capabilities*** Messages every ***tTypeCSendSourceCap***.
- Establishing PD Connection (no PD Connection or Contract):
  - Presence of a PD Capable Port Partner is detected either:
    - By receiving a ***GoodCRC*** Message in response to a ***Source_Capabilities*** Message.
    - By receiving ***Hard Reset*** Signaling.

- Establishing the initial Explicit Contract after an Attach, Hard Reset or Implicit Contract as a result of a Power Role Swap or Fast Role Swap):
    - The Source receives a Request Message from the Sink and, if this is a Valid request, responds with an ***Accept*** Message followed by a ***PS_RDY*** Message when its power supply is ready to source power at the agreed level. At this point an Explicit Contract has been agreed.
    - A DFP that does not generate SOP' or SOP'' Packets, is not required to detect SOP' or SOP'' Packets and Discards them.
- When in an Explicit Contract (***PE_SRC_Ready*** State):
    - The Source processes and responds (if a response is required) to all Messages received and sends appropriate Messages whenever its Local Policy requires:
        - The Source informs the Sink whenever its capabilities change, by sending a ***Source_Capabilities*** Message.
        - The Source will always have an $R_p$ value asserted on its CC wire used for collision avoidance.
        - When this Port is a DRP the Source can initiate or receive a request for the exchange of power roles. After the Power Role Swap this Port will be a Sink and in an Implicit Contract until an Explicit Contract is negotiated immediately afterwards.
        - When this Port is a DRD the Source can initiate or receive a request for an exchange of data roles. After a Data Role Swap the DFP (Host) becomes a UFP (Device). The Port remains a Source and the VCONN Source role remains unchanged.
        - The Source can initiate or receive a request for an exchange of VCONN Source role. During a VCONN Swap VCONN is applied by both Ports (make before break). The Port remains a Source and DFP/UFP roles remain unchanged.
    - The Source when it is the VCONN Source can communicate with a Cable Plug using SOP' or SOP'' Communication at any time it is not engaged in any other SOP Communications:
        - If SOP Packets are received by the Source, during SOP' or SOP'' Communication, the SOP' or SOP'' Communication is immediately terminated (the Cable Plug times out and does not retry)
        - If the Source needs to initiate an SOP Communication during an ongoing SOP' or SOP'' Communication (e.g., for a Capabilities change) then the SOP' or SOP'' Communications will be interrupted.
    - When the Source Port is also a DFP:
        - The Source can control the entry and exiting of modes in the Cable Plug(s) and control Modal Operation.
        - The Source can initiate Unstructured or Structured VDMs.
        - The Source can control the entry and exiting of modes in the Sink and control Modal Operation using Structured VDMs.
    - When the Source Port is part of a multi-port system:
        - Will issue GotoMin requests when the Power Reserve is needed.
- Detach or Communications Failure:
    - A Source detects plug Detach and takes VBUS down to ***vSafe5V*** within ***tSafe5V*** and ***vSafe0V*** within ***tSafe0V*** (i.e. using USB Type-C® Detach detection via CC).

- When the Source detects the failure to receive a ***GoodCRC*** Message in response to a Message within ***tReceive***:
  - Leads to a Soft Reset, within ***tSoftReset*** of the ***CRCReceiveTimer*** expiring.
  - If the Soft Reset process cannot be completed a Hard Reset will be issued within tHardReset of the ***CRCReceiveTimer*** to restore VBUS to USB Default Operation within ~1-1.5s:
    - When the Source is also the VCONN Source, VCONN will also be power cycled during the Hard Reset.
- When the Source operating in SPR PPS mode fails to receive periodic communication (e.g., a ***Request*** Message) from the Sink within ***tPPSTimeout***:
  - Source issues a Hard Reset and takes VBUS to ***vSafe5V***.
- When the Source operating in the EPR mode fails to receive periodic communication (i.e., an ***EPR_KeepAlive*** Message or any other Message) from the Sink within ***tSourceEPRKeepAlive***:
  - Source issues a Hard Reset and takes VBUS to ***vSafe5V***.
- Receiving no response to further attempts at communication is interpreted by the Source as an error (see Error handling).
- Errors during power transitions will automatically lead to a Hard Reset to restore power to default levels.

- Error handling:
  - Protocol Errors are handled by a ***Soft_Reset*** Message issued by either Port Partner, that resets counters, timers and states, but does not change the negotiated Voltage and current or the Port's role (e.g., Source, DFP/UFP, VCONN Source) and does not cause an exit from Modal Operation.
  - Serious errors are handled by ***Hard Reset*** Signaling issued by either Port Partner. A Hard Reset:
    - Resets protocol as for a Soft Reset but also returns the power supply to USB Default Operation (***vSafe0V*** or ***vSafe5V*** output) in order to protect the Sink.
    - Restores the Port's data role to DFP.
    - Restores the Port's power to its USB Default state
    - When the Sink is the VCONN Source it removes VCONN then the Source Port is restored as the VCONN Source.
    - Causes all *Active Modes* to be exited such that the Source is no longer in Modal Operation.
  - After a Hard Reset it is expected that the Port Partner will respond within tNoResponse. If this does not occur then ***nHardResetCount*** further Hard Resets are carried out before the Source performs additional Error Recovery steps, as defined in ***[USB Type-C 2.3]*** , by entering the ***ErrorRecovery*** state.

### 2.5.2 Sink Operation

- At Attach (no PD Connection or Contract):
  - Sink detects Source Attachment through the presence of ***vSafe5V***.
  - For a DRP that toggles between Source and Sink operation, the Port becomes a Sink Port on Attachment of a Source.
  - Once the Sink detects the presence of ***vSafe5V*** on $V_{BUS}$ it waits for a ***Source_Capabilities*** Message indicating the presence of a PD capable Source.
  - If the Sink does not receive a ***Source_Capabilities*** Message within ***tTypeCSinkWaitCap*** then it can issue ***Hard Reset*** Signaling in order to cause the Source Port to send a ***Source_Capabilities*** Message if the Source Port is PD capable.
  - The Sink does not generate SOP' or SOP'' Packets, is not required to detect SOP' or SOP'' Packets and does not recognize them.
- Establishing PD Connection (no PD Connection or Contract):
  - The Sink receives a ***Source_Capabilities*** Message and responds with a ***GoodCRC*** Message.
  - The Sink does not generate SOP' or SOP'' Packets, is not required to detect SOP' or SOP'' Packets and ***Discards*** them.
- Establishing the initial Explicit Contract after an Attach, Hard Reset or Implicit Contract as a result of a Power Role Swap or Fast Role Swap:
  - The Sink receives a ***Source_Capabilities*** Message from the Source and responds with a ***Request*** Message. If this is a ***Valid*** request the Sink receives an ***Accept*** Message followed by a ***PS_RDY*** Message when the Source's power supply is ready to source power at the agreed level. At this point the Source and Sink have entered into an Explicit Contract:
    - The Sink Port can request one of the capabilities offered by the Source, even if this is the ***vSafe5V*** output offered by ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 2.3]*** or ***[USBBC 1.2]***, in order to enable future power negotiation:
      - A Sink not requesting any capability with a ***Request*** Message results in an error.
    - A Sink unable to fully operate at the offered capabilities requests the default capability but indicates that it would prefer another power level by setting the Capability Mismatch bit in Request Message and also providing a physical indication of the failure to the End User (e.g., using an LED).
    - A Sink does not generate SOP' or SOP'' Packets, is not required to detect SOP' or SOP'' Packets and ***Discards*** them.
- During PD Connection (Explicit Contract – ***PE_SNK_Ready*** state):
  - The Sink processes and responds (if a response is required) to all Messages received and sends appropriate Messages whenever its Local Policy requires.
  - A Sink whose power needs have changed indicates this to the Source with a new ***Request*** Message. The Sink Port can request one of the capabilities previously offered by the Source, even if this is the ***vSafe5V*** output offered by ***[USB 2.0]***, ***[USB 3.2]***, ***[USB Type-C 2.3]*** or ***[USBBC 1.2]***, in order to enable future power negotiation:
    - Not requesting any capability with a ***Request*** Message results in an error.

        - A Sink unable to fully operate at the offered capabilities requests an offered capability but indicates a capability mismatch i.e., that it would prefer another power level also providing a physical indication of the failure to the End User (e.g., using an LED).
    - A Sink operating in the SPR PPS mode periodically sends ***Request*** Message within ***tPPSRequest*** even if its request is unchanged.
    - A Sink operating in the EPR mode periodically communicates with the Source (i.e., sends an ***EPR_KeepAlive*** Message or any other Message) within ***tSourceEPRKeepAlive***.
    - The Sink will always have $R_d$ asserted on its CC wire.
    - When this Port is a DRP, the Sink can initiate or receive a request for the exchange of power roles. After the Power Role Swap this Port will be a Source and an Implicit Contract will be in place until an Explicit Contract is negotiated immediately afterwards.
    - When this Port is a DRD the Sink can initiate or receive a request for an exchange of data roles. After a Data Role Swap the UFP (Device) becomes a DFP (Host). The Port remains a Sink and VCONN Source role (or not) remains unchanged.
    - The Sink can initiate or receive a request for an exchange of VCONN Source. During a VCONN Swap VCONN is applied by both ends (make before break). The Port remains a Sink and DFP/UFP roles remain unchanged.
    - The Sink when it is the VCONN Source can communicate with a Cable Plug using SOP' or SOP'' Communication at any time it is not engaged in any other SOP Communications:
        - If SOP Packets are received by the Sink, during SOP' or SOP'' Communication, the SOP' or SOP'' Communication is immediately terminated (the Cable Plug times out and does not retry)
        - If the Sink needs to initiate an SOP Communication during an ongoing SOP' or SOP'' Communication (e.g., for a Capabilities change) then the SOP' or SOP'' Communications will be interrupted.
        - When the Sink Port is also a DFP the Sink can control the entry and exiting of modes in the Cable Plug(s) and control Modal Operation (e.g., ***[USB4]***).
    - When the Sink Port is also a DFP:
        - The Sink can initiate Unstructured or Structured VDMs.
        - The Sink can control the entry and exiting of modes in the Source and control Modal Operation using Structured VDMs.
- Detach or Communications Failure:
    - A Sink detects the removal of $V_{BUS}$ and interprets this as the end of the PD Connection:
        - This is unless the ***vSafe0V*** is due to either a Hard Reset, Power Role Swap or Fast Role Swap.
    - A Sink detects plug removal (i.e., absence of $R_p$ or $V_{BUS}$) and discharges $V_{BUS}$.
    - When the Sink detects the failure to receive a ***GoodCRC*** Message in response to a Message within ***tReceive:***
        - Leads to a Soft Reset, within ***tSoftReset*** of the ***CRCReceiveTimer*** expiring.
        - If the Soft Reset process cannot be completed a Hard Reset will be issued within ***tHardReset*** of the ***CRCReceiveTimer*** to restore $V_{BUS}$ to USB Default Operation within ~1-1.5s.
        - Receiving no response to further attempts at communication is interpreted by the Sink as an error (see Error handling).

- When the Sink operating in the PPS mode fails to send periodic communication (i.e. a ***Request*** Message) to the Source within ***tPPSRequest***, the Source will issue a Hard Reset that results in $V_{BUS}$ going to ***vSafe5V***.
- When the Sink operating in the EPR mode fails to send periodic communication (i.e. an ***EPR_KeepAlive*** Message or any other Message) to the Source within ***tSourceEPRKeepAlive*** the Source will issue a Hard Reset that results in $V_{BUS}$ going to ***vSafe5V***.
- Errors during power transitions will automatically lead to a Hard Reset to restore power to default levels.

- Error handling:
  - Protocol Errors are handled by a ***Soft_Reset*** Message issued by either Port Partner, that resets counters, timers and states, but does not change the negotiated Voltage and current or the Port's role (e.g., Sink, DFP/UFP, VCONN Source) and does not cause an exit from Modal Operation.
  - Serious errors are handled by ***Hard Reset*** Signaling issued by either Port Partner. A Hard Reset:
    - resets protocol as for a Soft Reset but also returns the power supply to USB Default Operation (***vSafe0V*** or ***vSafe5V*** output) in order to protect the Sink.
    - restores the Port's data role to UFP.
    - when the Sink is the VCONN Source it removes VCONN then the Source Port is restored as the VCONN Source.
    - causes all *Active Modes* to be exited such that the Source is no longer in Modal Operation.
- After a Hard Reset it is expected that the Port Partner will respond within ***tTypeCSinkWaitCap***. If this does not occur, then two further Hard Resets are carried out before the UFP stays in the ***PE_SNK_Wait_for_Capabilities*** state.

### 2.5.3 Cable Plugs

- Cable Plugs are powered when VCONN is present but are not aware of the status of the Contract between the ports the cable assembly is connecting.
- Cable Plugs do not initiate message sequences and only respond to messages sent to them.
- Detach or Communications Failure:
  - Communications can be interrupted at any time.
  - There is no communication timeout scheme between the DFP/UFP and Cable Plug.
  - The Cable Plug is ready to respond to potentially repeated requests.
- Error handling:
  - The Cable Plug detects ***Hard Reset*** Signaling to determine that the Source and Sink have been reset and will need to reset itself (equivalent to a power cycle).
    - The Cable Plug cannot generate ***Hard Reset*** Signaling itself.
    - The Hard-Reset process power cycles both $V_{BUS}$ and Vconn so this is expected to reset the Cable Plugs by itself.
  - A Cable Plug detects ***Cable Reset*** Signaling to determine that it will need to reset itself (equivalent to a power cycle).

## 2.6 Architectural Overview

This logical architecture is not intended to be taken as an implementation architecture. An implementation architecture is, by definition, a part of product definition and is therefore outside of the scope of this specification.

This section outlines the high-level logical architecture of USB Power Delivery referenced throughout this specification. In practice various implementation options are possible based on many different possible types of PD device. PD devices can have many different configurations e.g., USB or non-USB communication, single versus multiple ports, dedicated power supplies versus supplies shared on multiple ports, hardware versus software-based implementations etc. The architecture outlined in this section is therefore provided only for reference to indicate the high-level logical model used by the PD specification. This architecture is used to identify the key concepts and to indicate logical blocks and possible links between them.

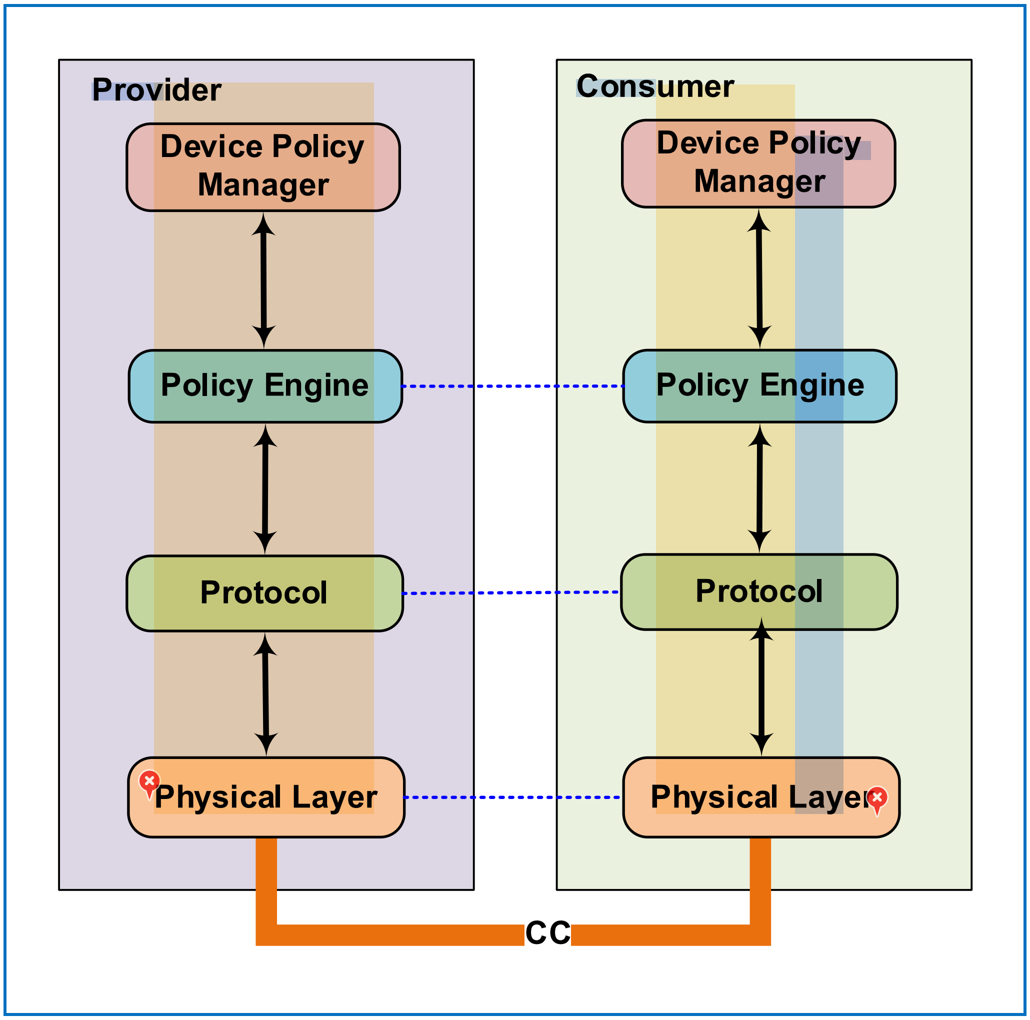
The USB Power Delivery is a Port to Port architecture in which each USB Power Delivery capable Device is made up of several major components.

- ***Figure 2-3 "USB Power Delivery Communications Stack"*** illustrates the relationship of the layers of the communications stack between a Port Pair.

The communications stack consists of:

- A Device Policy Manager (see ***Section 8.2 "Device Policy Manager"***) that exists in all devices and manages USB Power Delivery resources within the device across one or more ports based on the Device's Local Policy.
- A Policy Engine (see ***Section 8.3 "Policy Engine"***) that exists in each USB Power Delivery Port implements the Local Policy for that Port.
- A Protocol Layer (see ***Chapter 6 "Protocol Layer"***) that enables Messages to be exchanged between a Source Port and a Sink Port.
- A Physical Layer (see ***Chapter 5 "Physical Layer"***) that handles transmission and reception of bits on the wire and handles data transmission.

Figure 2-3 "USB Power Delivery Communications Stack"




Additionally, USB Power Delivery devices which can operate as USB devices can communicate over USB (see *Figure 2-4 "USB Power Delivery Communication Over USB"*). An ***Optional*** System Policy Manager (see Chapter 9 and *[UCSI]*) that resides in the USB Host communicates with the PD Device over USB, via the root Port and potentially manages the individual Port to Port connections over a tree of USB Hubs. The **Device Policy Manager** interacts with the USB interface in each device to provide and update PD related information in the USB domain. Note that a PD device is not required to have a USB device interface.

Figure 2-4 "USB Power Delivery Communication Over USB"

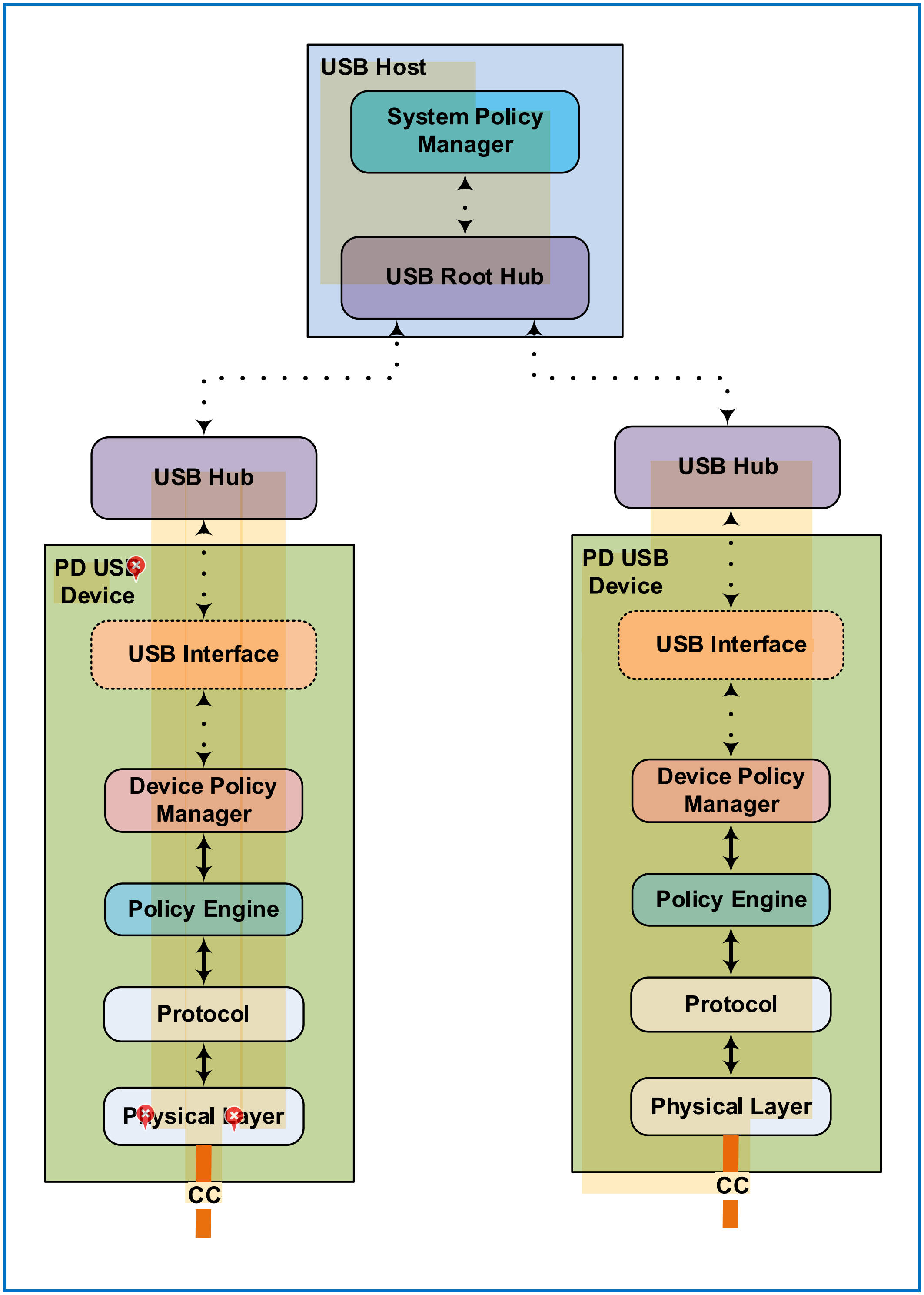



*Figure 2-5 "High Level Architecture View"* shows the logical blocks between two Attached PD ports (Port Pair). In addition to the communication stack described above there are also:

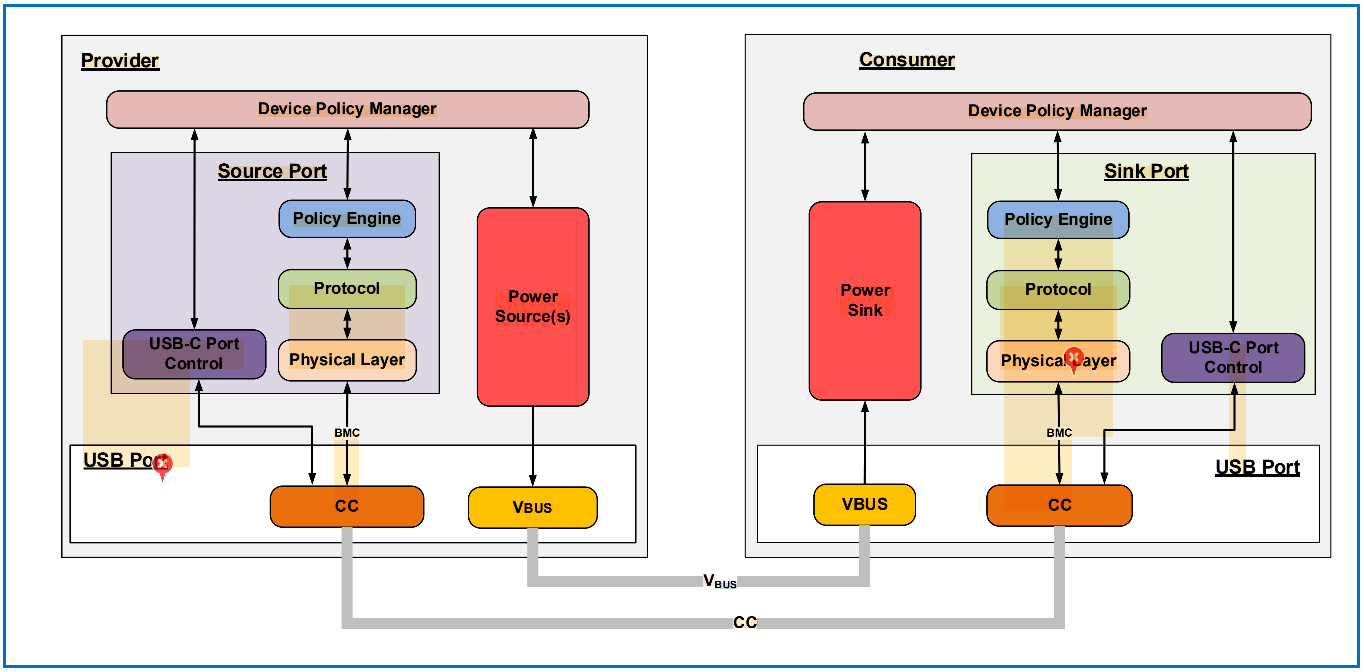
- For a Provider or Dual-Role Power Device: one or more **Sources** providing power to one or more ports.
- For a Consumer or Dual-Role Power Device: A **Sink** consuming power.

- A USB-C Port Control module (see *Section4.4 "Cable Type Detection"*) that detects cable Attach/Detach as defined in *[USB Type-C 2.3]*.
- USB Power Delivery uses standard cabling as defined in *[USB Type-C 2.3]*.

The **Device Policy Manager** talks to the communication stack, Source/Sink, and the USB-C Port Control block to manage the resources in the Provider or Consumer.

*Figure 2-5 "High Level Architecture View"* illustrates a Provider and a Consumer. Dual-Role Power Devices can be constructed by combining the elements of both Provider and Consumer into a single device. Providers can also contain multiple Source Ports each with their own communications stack and USB-C Port Control.

**Figure 2-5 "High Level Architecture View"**




## 2.6.1 Policy

There are two levels of Policy:

1) System Policy applied system wide by the System Policy Manager across multiple Providers or Consumers.

3) Local Policy enforced on a Provider or Consumer by the Device Policy Manager for a device.

Policy comprises several logical blocks:

- System Policy Manager (system wide).
- Device Policy Manager (one per Provider or Consumer).
- Policy Engine (one per Source or Sink Port).

### 2.6.1.1 System Policy Manager

Since the USB Power Delivery protocol is Port to Port, implementation of a System Policy requires communication by an additional data communication mechanism i.e., USB. *[UCSI]* has been created to define an interface for the System Policy manager to communicate with the Device Policy manager. When present, the System Policy Manager monitors and controls System Policy between various Providers and Consumers connected via USB. The System Policy

Manager resides in the USB Host and communicates via USB with the Device Policy Manager in each connected Device. Devices without USB data communication capability or are not data connected, will not be able to participate in System Policy.

The System Policy Manager is ***Optional*** so USB Power Delivery Providers and Consumers will operate without it being present. This includes systems where the USB Host does not provide a System Policy Manager and can also include "headless" systems without any USB Host. In those cases where a Host is not present, USB Power Delivery is useful for charging purposes, or the powering of devices since useful USB functionality is not possible. Where there is a USB Host, but no System Policy Manager, Providers and Consumers can negotiate power between themselves, independently of USB power rules, but are more limited in terms of the options available for managing power.

#### 2.6.1.2 Device Policy Manager

The Device Policy Manager provides mechanisms to monitor and control the USB Power Delivery system within a particular Consumer or Provider. The Device Policy Manager enables Local Policies to be enforced across the system by communication with the System Policy Manager. Local Policies are enacted on a per Port basis by the Device Policy Manager's control of the Source/Sink Ports and by communication with the Policy Engine and USB-C Port Control for that Port. The Device Policy Manager is responsible for the sharing algorithm used in shared capacity chargers (see ***[USB Type-C 2.3]***)

#### 2.6.1.3 Policy Engine

Providers and Consumers are free to implement their own Local Policies on their directly connected Source or Sink Ports. These will be supported by negotiation and status mechanisms implemented by the Policy Engine for that Port. The Policy Engine interacts directly with the Device Policy Manager to determine the present Local Policy to be enforced. The Device Policy Manager will also inform the Policy Engine whenever there is a change in Local Policy (e.g., capabilities change).

### 2.6.2 Message Formation and Transmission

#### 2.6.2.1 Protocol Layer

The Protocol Layer forms the Messages used to communicate information between a pair of ports. It is responsible for forming Capabilities Messages, requests and acknowledgements. Additionally, it forms Messages used to swap roles and maintain presence. It receives inputs from the Policy Engine indicating which Messages to send and indicates the responses back to the Policy Engine.

The basic protocol uses a push model where the Provider pushes it capabilities to the Consumer that in turn responds with a request based on the offering. However, the Consumer can asynchronously request the Provider's present capabilities and can select another Voltage/current.

Extended Messages of up to a Data Size of ***MaxExtendedMsgLen*** can be sent and received provided the Protocol Layer determines that both Port Partners support this capability. When one of both Port Partners do not support Extended Messages of Data Size greater than ***MaxExtendedMsgLegacyLen*** then the Protocol Layer supports a Chunking mechanism to break larger Messages into smaller Chunks of size ***MaxExtendedMsgChunkLen***. All ports that support extended messages longer than ***MaxExtendedMsgLegacyLen*** are required to support chunking.

#### 2.6.2.2 PHY Layer

The PHY Layer is responsible for sending and receiving Messages across the USB Type-C® CC wire and for managing data. PD is a multi-drop system that implements collision avoidance and recovery mechanisms on the wire. It also detects errors in the Messages using a CRC.

### 2.6.3 Collision Avoidance

#### 2.6.3.1 Policy Engine

The Policy Engine in a Source will indicate to the Protocol Layer the start and end of each Atomic Message Sequence (AMS) that the Source initiates. The Policy Engine in a Sink will indicate to the Protocol Layer the start of each AMS the Sink initiates. This enables co-ordination of AMS initiation between the Port Partners.

#### 2.6.3.2 Protocol Layer

The Protocol Layer in the Source will request the PHY to set the $R_p$ value to ***SinkTxOk*** to indicate that the Sink can initiate an AMS by sending the first Message in the sequence. The Protocol Layer in the Source will request the PHY to set the $R_p$ value to ***SinkTxNG*** to indicate that the Sink cannot initiate an AMS since the Source is about to initiate an AMS.

The Protocol Layer in the Sink, when the Policy Engine indicates that an AMS is being initiated, will wait for the $R_p$ value to be set to ***SinkTxOk*** before initiating the AMS by sending the first Message in the sequence.

#### 2.6.3.3 PHY Layer

The PHY Layer in the Source will set the $R_p$ value to either ***SinkTxOk*** or ***SinkTxNG*** as directed by the Protocol Layer. The PHY Layer in the Sink will detect the present $R_p$ value and inform the Protocol Layer.

### 2.6.4 Power supply

#### 2.6.4.1 Source

Each Provider will contain one or more power sources that are shared between one or more ports. These power sources are controlled by the Local Policy. Source Ports start up in USB Type-C Operation where the Port applies ***vSafe0V*** on $V_{BUS}$ and return to this state on Detach or after a Hard Reset. When the Source detects Attach events it transitions its output to ***vSafe5V***.

#### 2.6.4.2 Sink

Consumers are assumed to have one Sink connected to a Port. This Sink is controlled by Local Policy. Sinks start up in USB Default Operation where the Port can operate at ***vSafe5V*** with USB default specified current levels and return to this state on Detach or after a Hard Reset.

#### 2.6.4.3 Dual-Role Power Ports

Dual-Role Power Ports have the ability to operate as either a Source or a Sink and to swap between the two roles using Power Role Swap or Fast Role Swap.

#### 2.6.4.4 Dead Battery or Lost Power Detection

*[USB Type-C 2.3]* defines mechanisms intended to communicate with and to charge a Sink or DRP with a Dead Battery.

#### 2.6.4.5 VCONN Source

The initial Source Port, is also the VCONN Source. The responsibility for sourcing VCONN can be swapped between the Source and Sink Ports in a make before break fashion to ensure that the Cable Plugs are continuously powered. To ensure reliable communication with the Cable Plugs only the VCONN Source is permitted to communicate with the

Cable Plugs. Note prior to a Power Role Swap, Data Role Swap or Fast Role Swap each new Source Port needs to ensure that it is the VCONN Source if it needs to communicate with the Cable Plugs after the swap.

### 2.6.5 DFP/UFP

#### 2.6.5.1 Downstream Facing Port (DFP)

The Downstream Facing Port or DFP is equivalent in the USB topology to the Port a USB Device is attached to. The DFP will also correspond to the USB Host but only if USB Communication is supported while acting as a DFP. Products such as chargers (i.e., Wall Warts) can be a DFP while not having USB Communication capability. Only the DFP is allowed to control alternate mode operation.

#### 2.6.5.2 Upstream Facing Port (UFP)

The Upstream Facing Port or UFP is equivalent in the USB topology to the Port on a USB Device that is connected to the USB Host or Hub's DFP. The UFP will also correspond to the USB Device but only if USB Communication is supported while acting as a UFP. Products which charge can be a UFP while not having USB Communication capability.

#### 2.6.5.3 Dual-Role Data Ports

Dual-Role Data Ports have the ability to operate as either a DFP or a UFP and to swap between the two roles using Data Role Swap. Note that products can be Dual-Role Data Ports without being Dual-Role Power ports that is they can switch logically between DFP and UFP roles even if they are Source-only or Sink-only Ports.

### 2.6.6 Cable and Connectors

The USB Power Delivery specification assumes certified USB cables and associated detection mechanisms as defined in the ***[USB Type-C 2.3]*** specification.

#### 2.6.6.1 USB-C Port Control

The USB-C Port Control block provides mechanisms to:

- Inform the Device Policy Manager of cable Attach/Detach events.
- Inform Sink's Device Policy Manager of the $R_p$ value.
- Allow Source's Device Policy Manager to set $R_p$ value.

### 2.6.7 Interactions between Non-PD, BC, and PD devices

USB Power Delivery only operates when two USB Power Delivery devices are directly connected. When a Device finds itself a mixed environment, where the other device does not support the USB Power Delivery Specification, the existing rules on supplying ***vSafe5V*** as defined in the ***[USB 2.0]***, ***[USB 3.2]***, ***[USBBC 1.2]*** or ***[USB Type-C 2.3]*** specifications are applied.

There are two primary cases to consider:

- The Host (DFP/Source) is non-PD and as such will not send any Advertisements. An Attached PD capable Device will not see any Advertisements and operates using the rules defined in the ***[USB 2.0]***, ***[USB 3.2]***, ***[USBBC 1.2]*** or ***[USB Type-C 2.3]*** specifications.
- The Device (UFP/Sink) is non-PD and as such will not see any Advertisements and therefore will not respond. The Host (DFP/Source) will continue to supply ***vSafe5V*** to $V_{BUS}$ as specified in the ***[USB 2.0]***, ***[USB 3.2]***, ***[USBBC 1.2]*** or ***[USB Type-C 2.3]*** specifications.

### 2.6.8 Power Rules

Power Rules define Voltages and current ranges that are offered by compliant USB Power Delivery Sources and used by a USB Power Delivery Sink for a given value of PD Power. See ***Chapter 10 "Power Rules"*** for further details.

## 2.7 Extended Power Range (EPR) Operation

Extended Power Range is a mode provides for up to 240W which is considerably more power than the 100W the original PD specification (SPR operation) offered. It is a mode of operation that can be entered only when an Explicit Contract is in place and both the Ports and the Cable support EPR.

Entry into EPR Mode follows a strict process; this assures that the higher Voltages, at power levels above 100W, are only transferred between known EPR capable Sources and EPR capable Sinks over EPR capable cables. EPR Sources are capable of both Fixed and Adjustable Voltage Supply (AVS) operation. Maintaining EPR Mode operation also requires maintaining a regular cadence of USB PD communications; loss of communications between the Source and Sink will cause a Hard Reset to be initiated resulting in a return to SPR operation.

The EPR Mode entry, operational and exit process is summarized by the following steps:

1) Negotiate and enter into an Explicit Power Contract in the Standard Power Range. During this step, EPR-capable Sources and Sinks will declare their supported EPR capabilities through PDO/APDO and RDO exchanges.

4) An EPR Sink, having discovered an EPR Source, can request EPR Mode entry.

5) The EPR Source, upon receiving a EPR Mode entry request from the EPR Sink, will verify the attached cable assembly's EPR Capability.

6) The EPR Source, having confirmed the EPR cable, will respond to the EPR Sink with an acknowledgement of the EPR Mode entry request.

7) While in EPR Mode:

   a) The EPR Source sends EPR Capabilities (Fixed PDOs and an AVS APDO) to the EPR Sink which requires the Sink to evaluate and respond as appropriate to adjust the Explicit Power Contract.

   b) The EPR Sink maintains a regular cadence of communications with the EPR Source to allow EPR Mode to continue.

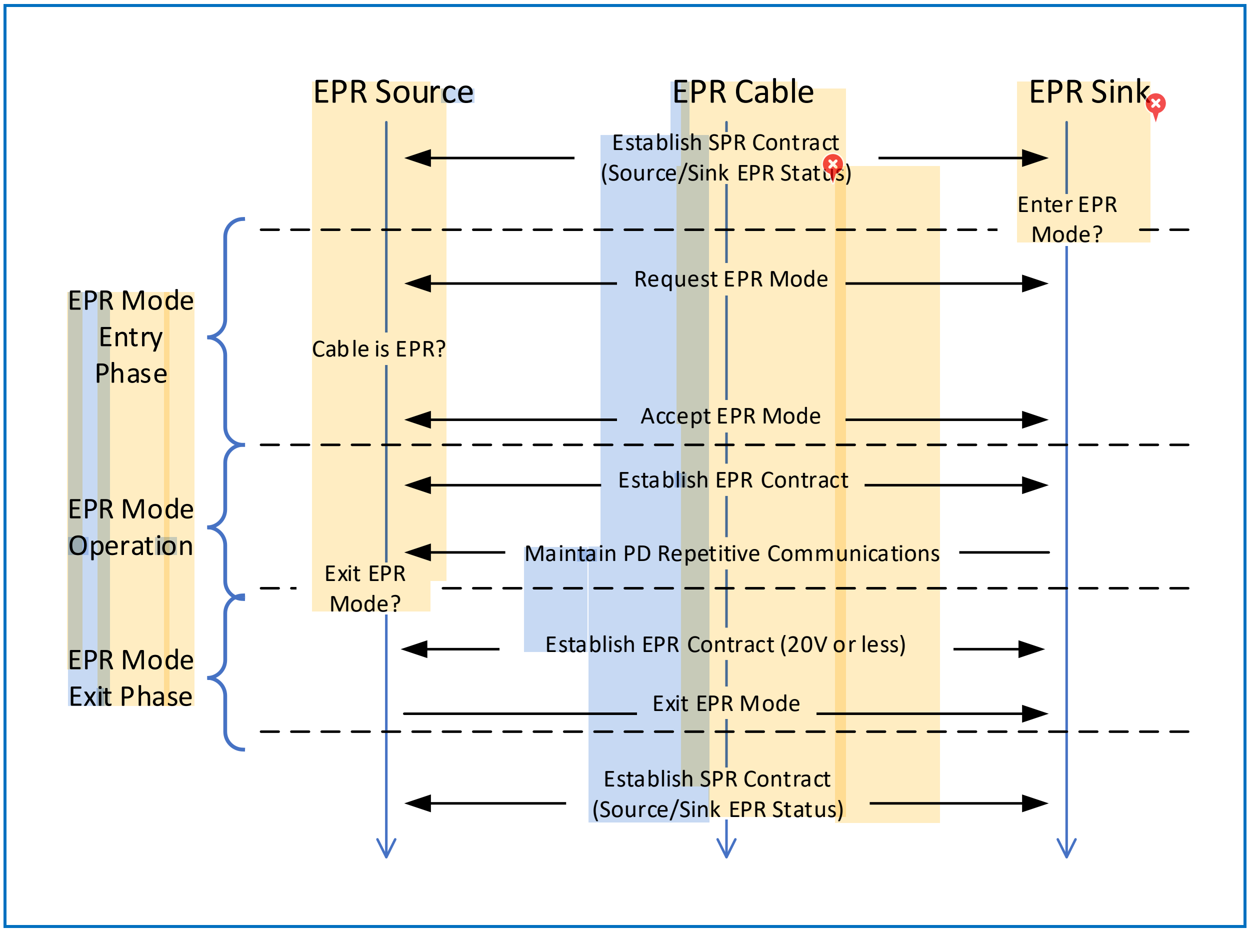
8) When either the EPR Source or EPR Sink no longer wants to remain in EPR Mode operation, a normal exit from EPR Mode will first require adjusting the Explicit Power Contract to a Voltage of 20V or lower (SPR (A)PDO) followed by an explicit EPR Mode exit request.

9) Source initiated: EPR Source sends an EPR capabilities message that only includes SPR Voltages to force the EPR Sink to drop to 20V or below followed by the EPR Mode exit. Once EPR Mode is exited, a new SPR contract is negotiated to formalize the return to SPR mode operation.

10) Sink initiated; EPR Sink requests a drop to 20V or below followed by the EPR Mode exit. Once EPR Mode is exited, a new SPR contract is negotiated to formalize the return to SPR mode operation.

*Figure 2-6 "Example of a Normal EPR Mode Operational Flow"* illustrates an example of a normal EPR Mode operational flow. In this example, at some time during the EPR Mode operation, the Source decides that it needs to exit EPR Mode, so it resends the EPR Capabilities to the Sink with only SPR PDOs to cause the Sink to drop to 20V or lower and then the Source follows with an EPR Mode exit message. Once EPR Mode is exited, a new SPR contract is negotiated to formalize the return to SPR mode operation.

Figure 2-6 "Example of a Normal EPR Mode Operational Flow"




Not illustrated in *Figure 2-6 "Example of a Normal EPR Mode Operational Flow"*, while in EPR Mode operation, the Sink might decide it wants to exit EPR Mode. In this case, the Sink must initiate the exit process by revising its contract with the Source at 20V or less followed with an ***EPR_Mode*** exit Message. Once EPR Mode is exited, a new SPR contract is negotiated to formalize the return to SPR mode operation. Failure to revise the contract to one at 20V or less before attempting to exit EPR Mode will result in a Hard Reset.

## 2.8 Charging Models

This section provides a charging model overview for each of the primary power delivery methods: fixed Voltage, Programmable Power Supply and Adjustable Voltage Supply.

### 2.8.1 Fixed Voltage Charging Models

USB Power Delivery supports Fixed Voltage charging using a set of defined standard Voltages with current available up to the limit of the Source's and cable's Advertised capacity. As summarized in ***Table 2.1 "Fixed Voltage Power Ranges"***, the standard Voltages are available in either the Standard Power Range (SPR) and/or the Extended Power Range (EPR).

**Table 2.1 "Fixed Voltage Power Ranges"**

| Power Range | Available Current and Voltages | | PDP Range | Notes |
|---|---|---|---|---|
| Standard Power Range (SPR) | 3A: | 5V, 9V, 15V, 20V | 15 – 60W | |
| | 5A[1]: | 20V | >60 – 100W | |
| Extended Power Range (EPR) | 3A[2]: | 5V, 9V, 15V, 20V | 15 – 60W | Requires entry into EPR Mode. |
| | 5A[2]: | 20V | >60 – 100W | |
| | 5A[2]: | 28V, 36V, 48V | >100 – 240W | |

1) Requires 5A cable.

2) Requires EPR cable.

### 2.8.2 Programmable Power Supply (PPS) Charging Models

USB Power Delivery includes support for Programmable Power Supply (PPS) charging using a set of defined standard Voltage ranges. With current up to the limit of the Source's and cable's Advertised capacity. Additionally, when operating in SPR mode the current is also limited by the Operating Current in the ***Request*** message. Note PPS operation is not available in EPR mode.

The standard Voltage ranges available in the Standard Power Range (SPR) for PPS are summarized in ***Table 2.2 "PPS Voltage Power Ranges"***.

**Table 2.2 "PPS Voltage Power Ranges"**

| Available Current | Prog | Min Voltage (V) | Max Voltage (V) | PDP Range |
|---|---|---|---|---|
| 3A | 9V Prog | 5 | 11 | 16 – 60W |
| | 15V Prog | 5 | 16 | |
| | 20V Prog | 5 | 21 | |
| 5A[1] | 20V Prog | 5 | 21 | 61 – 100W |

1) Requires 5A cable.

### 2.8.3 Adjustable Voltage Supply (AVS) Charging Models

USB Power Delivery operating in SPR mode (when PDP is higher than 27W) and EPR mode includes support for Adjustable Voltage Supply (AVS) charging using a set of defined standard Voltage ranges based on the Source's PDP rating.

The standard Voltage ranges available for AVS are summarized in *Table 2.3 "Adjustable Voltage Supply Voltage Ranges"*.

**Table 2.3 "Adjustable Voltage Supply Voltage Ranges"**

| PDP | SPR AVS | | | EPR AVS | | |
|---|---|---|---|---|---|---|
| | Minimum Voltage (V) | Maximum Voltage (V) | Maximum Available Current | Minimum Voltage (V) | Maximum Voltage (V) | Maximum Available Current |
| >27…45W | 9 | 15 | 3A | N/A | | |
| >45…60W | 9 | 20 | 3A | | | |
| >60…100W | 9 | 20 | 5A[1] | | | |
| 100…140W | 9 | 20 | 5A[2] | 15 | 28 | 5A[2] |
| >140…180W | 9 | 20 | 5A[2] | 15 | 36 | 5A[2] |
| >180…240W | 9 | 20 | 5A[2] | 15 | 48 | 5A[2] |

1) Requires a 5A Cable.

2) Requires an EPR Cable.

3) The maximum available SPR AVS current is determined by the maximum available current in the Fixed 15V PDO in the 9 – 15V range and Fixed 20V PDO in the 15 – 20V range.