Qualcomm Technologies, Inc.

QCA402x (CDB2x)

Programmer's Guide

80-YA121-142 Rev. D

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Revision history

Revision	Date	Description
A	March 2018	Initial release
B	July 2018	Added the following: ▪ Section 3.5.13, Antenna diversity ▪ Section 3.9.4.8.5, Validating an external certificate ▪ Section 3.9.4.8.6, Certificate expiration test ▪ Section 3.9.11.7, HTTP tunneling ▪ Section 3.9.17, Websocket Client ▪ Section 3.12.4.1, Importing persistent objects from certificate store ▪ Section 3.12.5.6.1, ECJPAKE algorithm ▪ Section 4.3.5, RAM dump collection and debugging Updated the following: ▪ Section 3.9.4.8, SSL certificate manager ▪ Section 3.9.4.11.1, Establish a connection ▪ Section 3.9.11.2, Terminate a connection ▪ Section 3.9.11.3, Set URL key-value pairs ▪ Section 3.9.11.6, Send an HTTP request Section 3.12.5.6, Key derivation
C	November 2018	Numerous updates have been made to chapters 3 and 4. Read the document in its entirety.
D	November 2018	Updated section 3.12.2.2, Create an object by populating its attributes

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1 Introduction to QCA402x

1.1 Purpose

This document provides information intended for a software developer that works with the QCA402x device and is used to enhance, extend, or adapt the reference source code to meet customer requirements. This document does not attempt to detail every subject; it enables the reader an opportunity to understand the various components and how they interact. A careful reading of the code can provide more understanding. The *QCA402x QAPI specification* (80-Y9381-7) document describes formal APIs, including valuable comments that describe each interface and parameter.

QCA402x refers to QCA4020 and QCA4024 devices throughout this document.

1.2 Conventions

Function declarations, function names, type declarations, attributes, and code samples appear in a different font. For example, `#include`.

Code variables appear in angle brackets. For example, `<number>`.

Commands to be entered appear in a different font. For example, **`copy a:*.* b:`**.

Button and key names appear in bold font. For example, Click **Save** or press **Enter**.

2 QCA402x system overview

This section provides an overview of the various features of the QCA402x device.

2.1 Packages

QCA402x is available in two packages:

- QCA4020 (BGA 11.2x11.2 mm) includes Arm Cortex-M4F application processor, an Arm Cortex-M0 connectivity processor, and a dedicated processor to support the Wi-Fi dual-band functionality.
- QCA4024 (68mQFN 8x8 mm) includes an Arm Cortex-M4F application processor and an Arm Cortex-M0 connectivity processor.

2.2 QCA402x processors

QCA402x contains two processors – Arm -Cortex-M4F and Arm-Cortex-M0.

The first processor is an Arm Cortex-M4F and is used as the application processor, which runs the Qualcomm® networking stack and the OEM application code.

The processor and memory subsystem attributes are as follows:

- Arm Cortex-M4F @ up to128 MHz
- Arm v7-M ISA (Thumb/Thumb-2)
- Single-precision floating point
- 704 KB SRAM: 300 KB available for customer code and data
- 512 KB ROM
- Memory-mapped, cached view of external QSPI flash. The cache is specified as 32 KB with 4-way associativity.

The second processor is an Arm Cortex-M0, which is used as the connectivity processor for the BLE and 802.15.4 subsystems.

The processor attributes are as follows:

- Arm Cortex-M0 @ 64 MHz
- Arm v6-M ISA (subset of Thumb/Thumb-2)
- 128 KB SRAM
- 384 KB ROM

QCA4024 implements two wireless subsystems on-chip: BLE v5.0 and 802.15.4 v2006.

In addition to the preceding two processors, QCA4020 also has a dedicated WLAN processor. It implements three wireless subsystems on-chip: 1 x 1 dual-band 11n Wi-Fi, BLE v5.0, and 802.15.4 v2006.

3 QCA402x framework and programming model

3.1 RTOS

An application can use QuRT™, ThreadX, or FreeRTOS APIs for real-time operating system (RTOS) services. ThreadX and FreeRTOS APIs are described in external documentation available on the Web. Qualcomm's QuRT APIs are considered part of the QAPI and are thoroughly described in *QCA402x QAPI Specification (80-Y9381-7)* documentation.

RTOS APIs perform the following:

- Create/destroy tasks or threads
- Wait for an event to be signaled/signal an event
- Acquire a mutex/release a mutex
- Decrement a semaphore (consume)/Increment a semaphore (produce)
- Wait for a timer to expire/set a timer to expire

3.2 Thread priorities

An application can use QuRT API to set thread priority to be assigned to a thread. Thread priorities are specified as numeric values in the range of 0 – 31 with 0 representing the highest priority. It is recommended to set user application thread priority to be greater than or equal to 20 to avoid starvation of system threads.

3.3 Low-power framework

QCA402x provides a highly configurable framework for achieving lowest possible power consumption. The framework consists of following independent sub-modules:

3.3.1 Processor power management

QCA402x consists of two CPUs with independently managed power states-

- Arm Cortex-M4F – Application Processor Sub-System (APSS) that runs upper-layer stack firmware. It can run at scalable clock frequencies of 32 MHz, 64 MHz, and 128 MHz.
- Arm Cortex-M0 - Connectivity Sub-System (CONSS) runs 802.15.4 and BLE firmware. This CPU runs at a fixed 64 MHz clock frequency.

CPU power states are managed by "Sleep" subsystem software that runs when CPU is idle. The sleep subsystem is use-case agnostic that is, it enters and exits low-power states in a manner that is transparent to the application software. At each idle cycle, sleep module analyzes multiple system properties to choose an appropriate power state. The following parameters have a role in choosing an appropriate power state:

- Sleep duration - Amount of time until the next wakeup event.
- Maximum interrupt latency - Maximum amount of latency that a non-scheduled interrupt can tolerate.

The following are the supported CPU power states are:

- Active – In this state, CPU is executing instructions. XIP and RAM memory is active.
- Light Sleep – In this state, CPU is clock gated. All RAM contents are retained.
- Deep Sleep – This is the lowest power state of the CPU. The CPU is turned off and CPU contents are not retained. RAM contents are retained but RAM banks enter low-power state. SPI-NOR flash access is turned off. Sleep subsystem manages the CPU state restoration on wakeup.

3.3.2 Operating mode framework

QCA402x defines a set of operating modes to achieve low power operation based on different application profiles. A particular operating mode is an active state of the target, which defines different levels of access to memory resources (RAM and XIP). The operating mode framework describes the mechanism for transitioning between different modes. The framework is orthogonal to the CPU power states (light sleep, deep sleep).

3.3.2.1 APSS operating modes

On APSS processor, the following three operating modes are present:

- Full Operating Mode (FOM) - FOM is the default operating mode when the target boots up. This memory mode has full access to RAM and Flash (XIP).
- Sensor Operating Mode (SOM) - SOM enables periodic wakeups to perform sensor measurements. The duty cycle of the wakeups is application-specific and can be configured prior to entering Sensor Mode. While running in SOM, only the memory banks associated with sensor mode operation are retained, The remaining FOM memory banks are turned off. In this mode:
  - All RAM banks except ones needed by SOM are turned off.
  - XIP access is turned off.
  - Networking services and wireless connectivity is disabled.
  - Only few peripherals are active.
  - This mode is designed to work in non-RTOS environment.
- Minimal Operating Mode (MOM)**:** This is the lowest power mode. In this mode, only 8 KB of RAM is turned on and all other memory and peripheral resources are turned off.

Table 3-1 Operating modes of functional use cases

Operating Mode	Memory State	Available Functionality	RTOS
Full Operating Mode (FOM)	All RAM On XIP On	All Networking Sensor read Connectivity Other functions	RTOS
Sensor Operating Mode (SOM)	8 KB AON RAM On Small number of other RAM banks On XIP Off	Limited Sensor read Sensor processing Wi-Fi/15.4/BLE functions are not available	Single threaded with no RTOS
Minimum Operating Mode (MOM)	Only 8 KB AON RAM On XIP Off	Very limited Determine OM to enter based on wake up event Enter chosen OM (load from FLASH)	N/A

3.3.2.1.1 SOM application image

Any part of application image that is intended to run in SOM mode must be accordingly placed in the SOM code and data region. Note that FOM region memory is not available in SOM mode, therefore, SOM application code does not overlap with FOM region. For details on placing object files in a region, see section 4.3.3.

Figure 3-1 shows the memory map for the three operating modes on APSS.

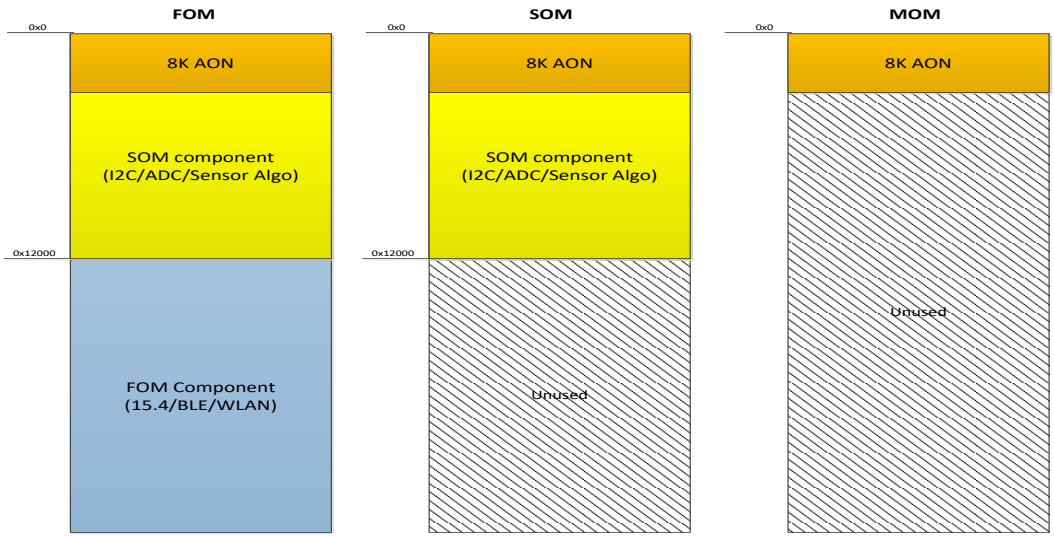


Figure 3-1 Memory map for the three operating modes on APSS

3.3.2.1.2 OMTM

Operating Mode Transition Manager (OMTM) is a software entity that manages mode transitions in response to application requests.The module provides a set of APIs allowing clients to request a change to a new Operating Mode. The client might request an immediate change or request that the OMTM wait for the system to be in a idle state before making the transition.

3.3.2.1.3 OMTT

1. An Operating Mode Transition Table (OMTT) describes all the possible transitions out of the current Operating Mode.
2. Each row in the OMTT table corresponds to a possible transition. The OMTT has the following columns-
   - **Target OM** – This field contains the identifier to which the Operating Mode is transitioned.
   - **Attribute** – This 32-bit field contains the OM attributes. Bit-0 corresponds to the XIP configuration (on/off).
   - **Whitelist** (addr, size) – This field contains a pointer to a whitelist structure containing the address and size of the code or data segment(s) to load from FLASH. The ALM active and sleep set configurations are derived from the whitelist. Some transitions does not require anything to be loaded from FLASH.In such a case, this field contains NULL.
   - **Entry Point** – For transitions that do not change the Scheduling Context, this field is NULL. For transitions that change the Scheduling Context, this field contains the entry point to which a switchover occurs to transfer control from the previous Operating Mode to the new Operating Mode.

The following table shows the example of the OMTT structure:

Table 3-2 OMTT structure

Target OM	Attributes	Whitelist (address,size)	Entry Point
MOM	.XIP = Off	NULL (to be updated)	MOM_main
SOM	.XIP = Off	{0x10000000, 68608}	SOM_main
FOM	.XIP = On	{0x10000000, 652288}	Main

All the operating modes must be registered with the OMTM module before any transition is requested. While switching between any operating mode, the image (or part of the image if it is a low memory operating mode) is reloaded and all the drivers/modules are reinitialized.

Figure 3-2 shows the state transition diagram for transition between different states.

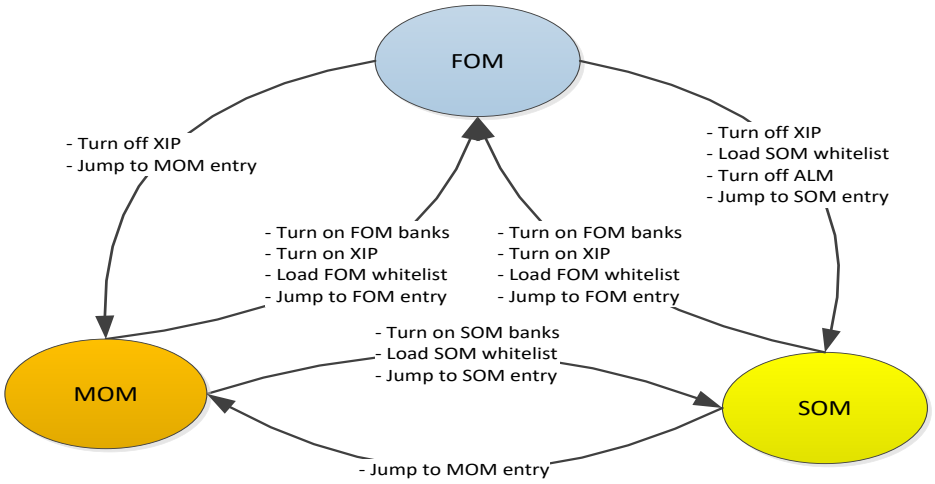


Figure 3-2 OMTM State Transitions

3.3.2.2 CONSS operating modes

On CONSS processor, the following three operating modesare present:

- Full Memory Mode (FMM): This is the default operating mode when the target boots. It has full access to RAM.
- Low Memory Mode (LMM): In this mode, some RAM banks are turned off.
- Minimal Memory Mode (MMM) In this mode, all the memory is turned off and the target enters deep sleep state. When the target wakes up, it goes through the cold boot sequence.

Similar to the APPS processor, switching between the operating modes, the image is reloaded and all the drivers/modules are reinitialized.

3.3.2.3 OMTM APIs

3.3.2.3.1 Register operating mode

```
qapi_Status_t qapi_OMTM_Register_Operating_Modes(
qapi_OMTM_Operating_Mode_t *modes,  uint32_t num_Modes, uint32_t
cur_Mode );
```

3.3.2.3.2 Register for a call-back when exiting a mode

```
qapi_Status_t qapi_OMTM_Register_Mode_Exit_Callback(
qapi_OMTM_Mode_Exit_CB_t func, void *user_Data, int32_t prio );
```

3.3.2.3.3 Switch operating mode

```
qapi_Status_t qapi_OMTM_Switch_Operating_Mode(uint32_t mode_Id,
qapi_OMTM_Switch_At_t when);
```

3.3.2.3.4 Switch CONSS memory mode

```
qapi_Status_t qapi_OMTM_Switch_ConSS_Memory_Mode(qapi_OMTM_ConSS_Mode_Id
mode_Id );
```

3.4 Communication drivers

3.4.1 802.15.4

The QCA402x modules include a IEEE 802.15.4-2006 MAC interface. The MAC implements the features for a nonbeacon PAN that are required for ZigBee and Thread operation. Features include the following:

- IEEE 802.15.4-2006 non-beacon PAN
- O-QPSK 2.4GHz PHY (Page 0, Channels 11-26).
- Hardware MAC acceleration for packet filtering and auto-acknowledgements.
- Full-function device (FFD) or reduced-function device (RFD) support
- MAC level security
  - Hardware accelerated AES128-CCM encryption
  - Automatic key rolling

- Auto-poll: MAC periodically polls a coordinator without intervention from the next higher layer.
- Vendor-specific commands for RF testing.

3.4.1.1 802.15.4 hardware

The 802.15.4 hardware includes a Hardware MAC (HMAC), Radio Control Unit (RCU), and modem (MDM). The 15.4 HMAC handles the following functions:

- Manages the MDM and RCU for transmitting and receiving packets.
- Schedules the commands.
- Automatic background tasks such as receive and energy scans.
- Appends FCS for transmitted packets and validates it for received packets.
- Parses and validates the frame header for received packets.
- Transmits and receives the acknowledgment automatically.
- Manages DMA buffer.

The 15.4 RCU handles ramp-up and ramp-down of the radio and the MDM handles the O-Quadrature phase-shift keying (O-QPSK) modulation and demodulation.

3.4.1.2 802.15.4 software

The 802.15.4 software executes on the Cortex-M0 and handles the core MAC functionality. A QAPI exits the Cortex-M4 to provide an application interface and interacts with the core MAC via an IPC layer.

The following features are supported by the 802.15.4 MAC:

- IEEE 802.15.4-2006 non-beacon PAN
- FFD and RFD support
- Security
- Mac data service (MCPS) primitives includes data and purge
- Mac layer management entity (MLME) service primitives includes associate, disassociate, beacon-notify, get, orphan, reset, Rx-enable, scan, comm-status, set, and poll.
- Additional vs. service primitives for auto-poll and RF testing.
- 802.15.4 security with hardware accelerated AES128-CCM support.

3.4.1.3 Auto-poll

The 802.15.4 MAC includes support for an auto-poll command, which allows the MAC to handle periodically check a coordinator for data without the need for periodic intervention from next higher layer.

This command sends a MAC data request (similar request is issued by the MLME-POLL.request primitive) on a periodic basis. If data is received on the poll, a MCSP-DATA.Indication is generated for the next higher layer.

Auto polling continues until it is stopped by next higher layer or the poll generates an error (most commonly, NO_ACK – A NO_DATA error does not stop polling).

3.4.1.4 802.15.4 security

While most of the MAC primitives are based directly on the 802.15.4 specification, the security functionality is modified for more efficient operation and additional features. The most significant change is to the Device and Key table PIBs.

According to the 802.15.4 specification, the key table PIB contains a list of all devices that can use the key. In this implementation, the key table only contains the information for the key and the entries in the device table have a field that ties it to the key being used. This implementation enables less memory usage for the key table and easy management of the table.

This mechanism also enables the addition of key rolling. A separation PIB provides an order that keys can rotate (as the attribute indexes into the key table). When a packet is received for a device, the MAC first checks if the key source matches the key the device uses. If it does not, the MAC checks each of the keys in the key rolling sequence that follow the key the device uses. If any of these matches the key source of the received packet, the MAC updates the information of the device to use that key and set its frame counter to match the received packet automatically. For security reasons, keys can only roll in the order specified by the key rotation sequence. If a packet is received for a key that is earlier in the sequence, it fails security checks.

3.4.2 Wi-Fi

The QCA4020 module includes a wireless LAN (WLAN) chipset that provides IEEE 802.11 WLAN network capability including:

- Wireless Media Access Control (MAC)
- Radio
- Baseband
- IEEE 802.11 protocol processing handled by an on-chip network processor

3.4.2.1 Wi-Fi hardware

QCA4020 is a combo chip that includes two dies namely, WLAN subsystem and rest of the system component which are connected through a standard SDIO interface.

The WLAN component includes a CPU, DMA engine, external memory controller, control logic, a wireless MAC and baseband, a radio, general purpose I/Os (GPIOs), serial port, and EJTAG.

The QCA4020 application processor communicates with the WLAN subsystem through standard interconnections such as SDIO or SPI bus protocol. The communication between the QCA4020 host and the WLAN chipset occurs primarily through messages sent through a mailbox (bi-directional FIFO queues) and special purpose registers on the WLAN subsystem. The mailboxes and registers are accessed through special addresses mapped to the device address space and through the services provided by a standard interconnect such as SPI or SDIO.

3.4.2.2 Wi-Fi software

The WLAN software in QCA4020 is partitioned into the application processor software (also referred to as WLAN host driver) and firmware that executes in WLAN subsystem. The WLAN firmware is loaded by the WLAN host driver when the application enables WLAN using the appropriate QAPI.

The WLAN firmware component is completely owned and maintained by Qualcomm and is supplied to customers only in binary form (conditions apply). The WLAN processor executes instructions from two sources, namely, an on-chip ROM and an instruction RAM (IRAM). The on-chip ROM instructions become available when WLAN subsystem is brought out of reset and IRAM instructions are loaded from external flash through the WLAN host driver when WLAN is enabled.

The WLAN software is architected in such a way that it comprises a thin host driver and a thin firmware which is executed on the WLAN processor. The motivation behind this architecture is to ensure easier portability of WLAN driver across various platforms from the legacy products.

WLAN host driver

The WLAN host software executes in the application processor of QCA4020 and includes the following major components:

- QAPI layer
- WLAN host driver
- Interconnect/bus drivers

QAPI layer – This is the top most layer of the WLAN host driver stack which exports bunch of APIs for applications to perform various WLAN operations. These WLAN operations include functionalities like scan, connect, and setting of various WLAN parameters.

WLAN host driver – This layer forms the core part of the WLAN host software and logically controls the WLAN hardware. This layer constitutes the control path and data path for WLAN subsystem. It receives a QAPI, processes it, and passes it onto WLAN firmware as necessary. On the reverse path, it generates events or passes the events from WLAN firmware to the application space. All data is passed across the interconnect to and from the WLAN chipset in 32-bit Little Endian format.

interconnect bus driver – This layer forms the bus-specific driver, which bridges bus-independent WLAN driver and platform-specific bus driver. Currently supported interconnects are SDIO/SPI drivers, of which SDIO is the primary mode of interconnection.

WLAN firmware

WLAN firmware executes in the WLAN processor and forms the major portion of the WLAN functionality. WLAN firmware includes various modules such as upper MAC, lower MAC, WPA supplicant, WPS supplicant, Wi-Fi Direct, and various offload features.

WLAN firmware implements handlers for various commands issued from the host driver and responds with appropriate response (if needed) through asynchronous events.

3.4.2.3 Wi-Fi host driver execution model

This section briefly discusses various execution thread context on which WLAN driver is executed in the application processor.

- Application thread – Any QAPI invoked by the application is executed in the context of application thread. The application thread may be blocked if the underlying QAPI performs a blocking operation in case of wireless scan operations. Most WLAN QAPIs tend to be non-blocking.
- WLAN Driver thread – This thread forms the crux of WLAN driver. Because all pending requests are sent to WLAN driver queue, regardless of data or control messages, they are handled in the context of this thread. The WLAN driver thread is also responsible for notification of various events to applications through asynchronous callback which is registered by the application at the time of WLAN enablement.
- Generic Timer thread – Any callback registered with timers started by WLAN driver executes in this context. Although the WLAN callback is invoked in this context, this callback is lightweight callback and wakes up WLAN driver with appropriate timer expiry information. The actual processing of timer is performed in the context of WLAN driver thread.
- Bus Interrupt Handler (High Priority Interrupt Thread) – On reception of control or data messages from the WLAN target, the relevant bus interrupt handler invokes the registered callback function of WLAN driver. The WLAN host software performs minimal, but extremely time critical operations in this callback and wakes up the driver thread for further processing.

3.5 WLAN features

3.5.1 Store-recall (Suspend-resume) of WLAN firmware

Suspend/Resume (store-recall) is the mechanism, where user can turn OFF (chip power-down) the WLAN module for certain duration and turn ON again without impacting the existing state of WLAN firmware for example, connection, socket, IP and so on.

During suspend time, the host (M4) stores the WLAN firmware information (called dsets) and restores it after the suspend time expires. WLAN firmware sends Null data frame with PM=1 to AP before entering to suspend state. After resuming, WLAN firmware sends the Null data frame PM=0 to AP. Sending of Null data during suspend-resume configurable using devconfig that is "SYS_TUNE_WLAN_NULL_PACKET_ENABLE". By default, this flag is enabled.

Use __QAPI_WLAN_PARAM_GROUP_SYSTEM_ENABLE_SUSPEND_RESUME to enable the store-recall feature. By default, this feature is enabled.

Use qapi_WLAN_Suspend_Start() API to suspend the wlan firmware.

NOTE: User can perform Store-recall operation only when the DUT is running on STA or p2p Client mode. This operation is not supported while DUT is operating on SoftAP/P2PGO mode or both devices (dev0 and dev1) are in connected case.

3.5.2 Packet Filtering and Wake on Wireless (WoW)

Packet filtering feature enables WLAN firmware/target to filter received packets that do not match the filter rule. This feature is supported in Active state or Suspend state. Each defined packet filtering rule is based on protocol type. The pattern matching algorithm is applied from start of protocol header at offset defined by filter rule. The following parameters define filtering rule:

- Pattern Index: Index that identifies the filtering pattern. User can choose the index from 1 to 8. 'Index 0' is reserved for default filter in each protocol header type.

3. Action Flag: Accept/Reject/Defer/Wake-on-wireless (WoW) Flag.
    a. ACCEPT Flag: If the pattern matches and action is ACCEPT, packet is given to host.
    b. REJECT Flag: If the pattern matches and action is REJECT, packet is rejected.
    c. DEFER Flag: If the pattern matches and action is DEFER, packet is given to next higher protocol type.
    d. WoW Flag: WoW flag enables the target to trigger out of band interrupt to Host (M4).

Priority: Priority associated with the filter rule. Target filter rule is based on priority and any match found (with Accept/Reject/Defer action) breaks from further processing of filter list. Priority 0 is reserved for default filter in each protocol header type.

Header Type: 802.3/SNAP/IPv4/IPv6/ICMP/ICMPv6/UDP/TCP/PAYLOAD

Offset: Offset from the header to which pattern match algorithm is applied.

Pattern Size: Size of pattern to search for in the received packet.

Pattern Mask: Mask to perform selective pattern match. Each bit in the mask correspond to byte in the pattern. If a bit is not set, the corresponding byte in the pattern is ignored. Else, the byte in the pattern mask is matched against the received byte.

Pattern: Maximum support pattern length is 128 bytes (value must be given in hexadecimal format)

Target maintains an array of list of pattern rule. Pattern rules are grouped by protocol and each protocol is list of priority-based sorted pattern. Firmware packet filtering module parses each packet protocol header and checks if packet filtering required or not. Header length may also vary based on optional field in IP header or TCP header. The pattern matching algorithm in performs the following events:.

- If packet filtering not enabled, forward packet to upper layer.
- Phrase the received packet and get L2/L3/L4 layer attributes such as header length, offset, and protocol.
- Based on the attributes, search the pattern list for match.
- Pattern search is 4 bytes operation after apply mask.
- If Action flag is WoW, wake up host(M4) using out of band interrupt
- If found, ACCEPT – forward to host, REJECT – drop the packet. DEFER – check for high-level protocol pattern

For more information on packet filter configuration, refer to *QCA402x Development Kit User Guide* (80-YA121-140).

3.5.3 ARP and NS offload

WLAN firmware internally processes and performs protocol and address check on the received ARP/NS frames. Firmware internally constructs and responds with appropriate ARP/NS response to the sender without waking up the host by forwarding ARP/NS packets.

3.5.4 TCP Keepalive offload

TCP Keepalive Offload feature is used to offload TCP packet exchange to the firmware after the initial TCP connection is formed between the TCP client and the server. This means that WLAN firmware can check the connected TCP socket, and determine whether the connection is still up and running or if it is broken.

When the TCP connection is setup, WLAN firmware associates a set of timers and after the Keepalive timer reaches 0, firmware sends a Keepalive probe packet with no data. At this stage, the ACK flag is turned ON and a reply is expected to be received from the peer with no data and the ACK set.

If firmware receives a reply to a Keepalive probe, firmware can assert that the connection is still up and running. If the peer does not respond to a Keepalive probe r, firmware can assert that the connection cannot be valid. Because WLAN firmware takes care of TCP Keepalive transmissions, s the application processor enters suspend-state for longer durations.

For more information, refer to *QCA402x Development Kit User Guide* (80-YA121-140).

3.5.5 Debug logs

Debug logs mechanism is used to collect the debug prints or information across different modules of system. For more information, see Chapter 5.

3.5.6 MAC Keepalive timeout for STA

This feature is used to keep station connection alive with AP by sending keepalive packets. A NULL data frame with power management bit set at certain intervals is sent if there is no data traffic, which ensures that the AP does not disconnect/deauthenticate the STA.

3.5.7 Channel switch

When DUT operates on QCMobileAP mode, this feature can be used to trigger the channel switch announcement on BSS before switching to new channel. For example, a QCMobileAP that detects significant traffic from neighboring BSSs on the secondary channel, or significant traffic on the primary channel for that matter, could move the BSS to a channel pair with less traffic and/or narrow the operating channel width.

The decision to switch channels is made by the QCMobileAP in BSS and the QCMobileAP must select a new channel that is supported by all associated stations. The AP informs associated stations that the BSS is moving to a new channel and/or changing operating channel width in the Channel Switch Announcement element in beacon frames and probe response frames, so that the associated STA's connected to QCMobileAP can move to the new operating BSS channel. The QCMobileAP attempts to schedule the channel switch, so that all stations in the BSS, including stations that are in

power-save mode, receives at least one Channel Switch Announcement element before the switching of channel occurs.

A scheduled channel switch occurs just before a target beacon transmission time (TBTT). The Channel Switch Count field indicates the number of TBTTs until the switch, including the TBTT just before which the switch occurs. A value of 1 indicates that the switch occurs just before the next TBTT. Whenever DUT operates in STA mode, after the DUT receives a channel switch Information Element from a connected BSS in the beacon or probe response frame, it stops transmission on the current channel until the transition moves to a new operating channel.

3.5.8 11v support

QCA402x supports 11v features both in station and QCMobileAP mode. Presently it supports WNM sleep and BSS max idle period in STA and QCMobileAP mode respectively.

3.5.9 WNM sleep

The WNM-Sleep Interval field (16 bits) STA indicates to the AP how often a STA in WNM-Sleep Mode wakes up to receive beacon frames, defined as the number of DTIM intervals. And Sleep interval for the station must be less than BSS max idle period advertised by the AP in beacons. STA must be connected to AP which supports the 11v feature.

3.5.10 SetAPBssMaxIdlePeriod

The BSS Max Idle period is the timeframe during which an access point (AP) does not disassociate a client due to nonreceipt of frames from the connected client. The idle time value indicates the maximum amount of time for which a client can remain idle without transmitting any frame to an AP.

Refer to QCA402x *Development Kit User Guide* (80-YA121-140) to configure the 11v functionality on DUT and further information.

3.5.11 Event filtering

This feature enables the user to filter the event between application processor and WLAN firmware. User can filter up to 64 events from WLAN firmware. These events are discarded in WLAN firmware so that it avoids application processor wakeups.

3.5.12 P2P module and P2P power-save mechanism

The peer-to-peer (P2P) module implements a solution for Wi-Fi Peer-to-Peer connectivity which allows Wi-Fi devices to communicate each other without access point.

There are three components in P2P module: P2P device, P2P Group Owner role and P2P Client role.

- After P2P module is enabled, Wi-Fi device works as a P2P device and P2P devices can find each other through device discovery.
- The P2P Group Owner role is "AP-like" entity that provides BSS functionality and services for associated clients.
- The P2P Client role implements non-AP STA functionality.

One of the following three methods is used to start a P2P Group:

- A P2P device autonomously starts a P2P Group by becoming a P2P Group Owner, other P2P clients connect to P2P Group Owner using WSC method;

4. Two P2P devices use the Group Formation to determine which device that functions as the P2P Group Owner and the device that functions as the P2P Client and form a new P2P Group;
5. A P2P device can invoke a Persistent P2P Group for which both P2P Devices have previously been provisioned. One of the devices is P2P Group Owner for Persistent P2P Group, and the P2P Group Owner or P2P Client can invite another P2P device to join its P2P Group.

P2P power-save mechanism is based on existing PS and WMM-PS power management delivery mechanisms with two new procedures that allow the P2P Group Owner to be absent for defined periods: Opportunistic Power Save and Notice of Absence.

- Opportunistic Power Save is a power management scheme that allows a P2P Group Owner to gain additional power savings on an opportunistic basis.
- The P2P Group Owner use P2P Notice of Absence attribute within transmitted beacon frames, probe response frames or Notice of Absence Action frames to inform its associated client of the planned absence timing.

3.5.13 Antenna diversity

The antenna diversity algorithm dynamically configures the best antenna based on RSSI, to improve the quality and reliability of a wireless link among the multiple antennas on board.

To enable the antenna diversity feature, the hardware platform must support multiple antennas and also have a fast RF switch to switch between antennas that meets specific requirements.

The antenna diversity algorithm selects the best antenna based on comparison of signal strength on each antenna to communicate with the peer. The comparison of signal strength can be based on the specific packet number, the specific time interval, or auto mode. If the signal strength of the in-use antenna is strong enough, this feature may not try to pick up other antennas.

Refer to *QCLI WLAN subgroups* section of *QCA402x Development Kit User Guide* (80-YA121-140) to configure antenna diversity, set physical antenna, and get antenna diversity statistics.

3.5.14 WPA Enterprise

This feature implements WPA Enterprise, which is also referred as WPA-802.1x or just WPA as opposed to WPA-PSK. It is available with both WPA and WPA2, and is designed for enterprise network. It requires a Remote Authentication Dial-In User Service (RADIUS) authentication server and provides various kinds of EAP methods for authentication.

The tested RADIUS authentication servers are open source FreeRADIUS, Microsoft IAS, and open source Hostapd. The tested EAP methods are EAP-TTLS/MSCHAPv2, PEAPv0/EAP-MSCHAPv2, EAP-TLS.

Based on the open source supplicant, the QCA4020 WPA supplicant module imports EAP related source codes, creates new eloop and socket Rx/Tx, and implements SSL adaptive layer on top of sharkssl.

To enable this feature, link the 8021x supplicant related library, and call the respective QAPIs. Refer to *QCLI WLAN subgroups* section of *QCA402x Development Kit User Guide* (80-YA121-140), which list the supported commands for demonstration.

3.6 NVM configuration

NVM values impact the configuration of the Qualcomm® Bluetooth Low Energy, 802.15.4, and coexistence subsystems. Default configuration values are already available to the system at boot, but the defaults might be modified in the application build using the following information.

The ".nvm" files provided in the "/quartz/nvm/config/" directory contain the default values. Demo application build scripts provided in the SDK automatically convert to C array and link the correct NVM file from this directory. However, an option is also given to use an NVM file from another directory. It is not necessary to provide all tag values from an NVM file if the default values are to be used; the full set of default values in the SDK is provided only for ease of use. For instance, an NVM file may contain only one tag whose default values are to be overwritten.

3.6.1 BLE NVM parameters list

NVM parameters are grouped into tags. The format and length of the NVM parameters are different for each tag. The minimum length is one byte. The byte order of the tag is the little-endian format, which follows the Bluetooth Host Controller Interface (Transport Layer) specification. The little-endian tag format places the least significant byte (LSB) at the first position of the tag and the most significant byte (MSB) at the last position of the tag.

Tag number	Name	Length (byte)
1	BLE Size Parameters	13
3	BLE Tx Power Level Table	32
5	Bluetooth Public Address	6
7	BLE Default Tx Power	2
8	BLE Low Power Drift Rate	2
10	BLE RF Compensation	4
17	BLE RCU FEM Tx Control	12
18	BLE RCU FEM Rx Control	12

3.6.1.1 BLE size parameters

Tag number: 1

Length: 13

Title	Options	Default/bit range	Description
BLE Size Parameters		0x51 00 72 06 04 10 10 14 14 03 01 FB 00	Tag number 1 is used to tweak BLE parameters related to various packet/buffer/list sizes. This can be tweaked to increase/decrease memory consumption at the expense of other factors (number of connections and throughput)

Title	Options	Default/bit range	Description
Maximum BLE Data Payload (byte 0-1)		0x5100	This number corresponds to the maximum data payload that can be set with HCI LE Set Data Length command. The value is 81 bytes (0x0051) by default
Maximum Extended Advertising Data Length (byte 2-3)		0x0672	This number corresponds to the maximum extended advertising buffer that can be given to the BLE controller. The default value is 1650. The maximum value is 1650.
Maximum simultaneous BLE connections (byte 4)		0x04	The maximum number of simultaneous BLE connections that are allowed. The value is 4 by default. The maximum value is 10.
Transmit Buffers (byte 5)		0x10	The number of ACL buffers dedicated to hold transmit data. The default value is 16.
Receive Buffers (byte 6)		0x10	The number of ACL buffers dedicated to hold receive data. The default value is 16.
Resolving List Size (byte 7)		0x14	The maximum number of entries reserved in the resolving list. The default value is 20.
White List Size (byte 8)		0x14	The maximum number of entries reserved in the white list. The default value is 20.
Max Advertising Reports Pending (byte 9)		0x03	The maximum number of advertising reports that can be pending for transmit to the host. The default value is 3.
Max Advertising Sets (byte 10)		0x01	The maximum number of extended advertising sets supported by the controller. The default value is 1. The maximum value is 4.
Max Extended Advertising Data Fragment Length (byte 11)		0xFB	The maximum length in which extended advertising data is fragmented before transmission. The default value is 251. The maximum value is 251.
Max Scan Request Receive Events (byte 12)		0x0	The maximum number of scan requests received HCI events that are buffered for dispatch to the host. The default value is 0.

3.6.1.2 BLE Tx power level table

Tag number: 3

Length: 32

Title	Options	Default/bit range	Description
BLE Tx Power Level Table (byte 0-31)		0xB8 F5 DA F6 C3 F7 80 F8 80 F9 4D FA 00 FC 45 FC F3 FC D7 FD CF FE 70 FF C5 01 8E 02 85 03 4D 04	This tag contains the table to map power level values (0-15) to dBm. Each entry is 2 bytes in size. The value for each entry in the table is the dBm * 256. It can also considered as a fixed-point number with 8 integers and 8 fractional bits.

3.6.1.3 Bluetooth public address

Tag number: 5

Length: 6

Title	Options	Default/bit range	Description
Bluetooth Public Address (byte 0-5)		0x00 00 00 00 00 00	Tag number 5 is used to allow a customer to program their own public Bluetooth address to differentiate from the one stored in OTP. When NVM Tag 5 is set as 0x000000000000, Bluetooth Public Address stored in OTP is used.

3.6.1.4 BLE default Tx power

Tag number: 7

Length: 1

Title	Options	Default/bit range	Description
BLE Default Tx Power (byte 0−1)		0x0404	Tag number 7 is used to set the default Tx Power level for BLE connections and advertising use cases. The values are specified in dBm units. If the controller does not support the exact power level specified, then the closest supported power level smaller than the appropriate power level is chosen.
	Advertising channel	Default: 0x04	Default Tx Power level used for advertising.
	Data channel	Default: 0x04	Default Tx Power level used for connections.

3.6.1.5 BLE Low Power Drift Rate

Tag number: 8

Length: 2

Title	Options	Default/bit range	Description
BLE Low Power Drift Rate (byte 0−1)		0xF4 01	This parameter contains PPM drift rate for the low power oscillator used for window-widening calculations and is reported to the remote device via the in the CONNECT_IND, AUX_CONNECT_REQ, and AUX_ADV PDU's. The default value is 500 and the maximum value is 500.

3.6.1.6 BLE RF compensation

Tag number: 10

Length: 4

Title	Options	Default/bit range	Description
BLE RF Compensation (byte 0−3)		0x0000	This tag contains the RF Path compensation values that are returned when the host queries the controller via the LE Read RF Path Compensation Command.
Tx RF compensation		0x00	Tx RF Compensation represented as a signed integer. Default value is 0.
Rx RF compensation		0x00	Rx RF Compensation represented as a signed integer. Default value is 0.

3.6.1.7 BLE RCU FEM Tx control

Tag number: 17

Length: 24

Title	Options	Default/bit range	Description
BLE RCU FEM Tx Control (byte 0-23)		0xFF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF	This tag contains the Front-End Module controls for assertion logic during BLE transmit operations.
On 0		0xFFFF	
On 1		0xFFFF	
On 2		0xFFFF	
On 3		0xFFFF	
On 4		0xFFFF	
On 5		0xFFFF	
Off 0		0xFFFF	
Off 1		0xFFFF	
Off 2		0xFFFF	
Off 3		0xFFFF	
Off 4		0xFFFF	
Off 5		0xFFFF	

3.6.1.8 BLE RCU FEM Rx control

Tag number: 18

Length: 24

Title	Options	Default/bit range	Description
BLE RCU FEM Rx Control (byte 0-23)		0xFF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF	This tag contains the Front End Module controls for assertion logic during BLE receive operations.
On 0		0xFFFF	
On 1		0xFFFF	
On 2		0xFFFF	
On 3		0xFFFF	
On 4		0xFFFF	
On 5		0xFFFF	
Off 0		0xFFFF	

Title	Options	Default/bit range	Description
Off 1		0xFFFF	
Off 2		0xFFFF	
Off 3		0xFFFF	
Off 4		0xFFFF	
Off 5		0xFFFF	

3.6.2 802.15.4 NVM parameters list

NVM parameters are grouped into tags. The format and length of the NVM parameters are different for each tag. The minimum length is one byte. The byte order of the tag is the little-endian format, which follows the Bluetooth Host Controller Interface (Transport Layer) Specification. The little-endian tag format places the least significant byte (LSB) at the first position of the tag and the most significant byte (MSB) at the last position of the tag.

Tag Number	Name	Length (byte)
52	Extended Address	8
54	Device Buffer	3
55	Security Config	2
56	Scan Config	1
57	Rx Hash Table	1
58	Tx Power Level	1
63	IPC Config	5

3.6.2.1 Extended address

Tag number: 52

Length: 8

Title	Options	Default/bit range	Description
Extended Address		0x0000000000000000	EUI-64 address of the MAC. If set to zero, the address is read from OTP.

3.6.2.2 Device buffer

Tag number: 54

Length: 3

Title	Options	Default/bit range	Description
Device Buffer		0x04 02 04	Tag number 54 is used to set the size of the 15.4 packet queues and device table.
Indirect Packet Count (byte 0)		Default: 0x04	The number of indirect packets that can be queued into the MAC.
Direct Packet Count (byte 1)		Default: 0x02	The number of direct packets that can be queued into the MAC.
Device Table Size (byte 2)		Default: 0x04	The size of the device table of MAC. This determines the number of remote devices that the MAC can store information for at a given time.

3.6.2.3 Security config

Tag number: 55

Length: 2

Title	Options	Default/bit range	Description
Security Config		0x04 04	Tag number 55 is used to set the size of the 15.4 key and security level tables.
Key Table Size (byte 0)		Default: 0x04	The size of the MAC's key table.
Security Level Table Size (byte 1)		Default: 0x04	The size of the MAC's security level table.

3.6.2.4 Scan config

Tag number: 56

Length: 1

Title	Options	Default/bit range	Description
Security Config		0x02	Tag number 56 is used to set the size of the PAN descriptor list for scan results.
PAN Descriptor List Size (byte 0)		Default: 0x02	The maximum number of PAN descriptors that can be provided in a MLME-SCAN.confirm packet.

3.6.2.5 Rx hash table

Tag number: 57

Length: 1

Title	Options	Default/bit range	Description
Rx Hash Table		0x03	Tag number 57 is used to set the size of the hash table used to detect duplicate 15.4 packets. Larger values are less likely to have conflicts, but consumes more RAM.
Rx Hash Table Size (byte 0)		Default: 0x03	Size of the hash table used for duplicate packet detection on received packets.

3.6.2.6 Tx power level

Tag number: 58

Length: 1

Title	Options	Default/bit range	Description
Tx Power Level		0x0A	Tag number 58 is used to set the default transmit power used by the 15.4 MAC.
Default Tx Power Level (byte 0)		Range: 0x0-0x0F Default: 0x0F	Power level in the range of 0x00 to 0x0F

3.6.2.7 IPC config

Tag number: 63

Length: 5

Title	Options	Default/bit range	Description
Security Config		0x00 02 08 04 08	Tag number 58 is used to tweak the size of the buffers used to send commands from the M4 to the MAC.
IPC Rx buffer Size (byte 0-1)		Default: 0x0200	Size of the IPC receive buffer in bytes.
Rx Credit Count (byte 2)		Default: 0x08	The number of packets from the M4 that can be queued into the MAC for processing.
Rx Credit Threshold (byte 3)		Default: 0x04	The threshold at which Rx credits are granted to the M4.
Tx Queue Threshold (byte 4)		Default: 0x08	The threshold for the event queue (m0 – m4) at which the 15.4 receiver is disabled. This prevents possible packet loss if the M4 processes 15.4 packets for long periods.

3.6.2.8 15.4 RCU FEM Tx control

Tag number: 73

Length: 24

Title	Options	Default/bit range	Description
15.4 RCU FEM Tx Control (byte 0-23)		0xFF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF	This tag contains the front-end module controls for assertion logic during 15.4 transmit operations.
On 0		0xFFFF	.
On 1		0xFFFF	
On 2		0xFFFF	
On 3		0xFFFF	
On 4		0xFFFF	
On 5		0xFFFF	
Off 0		0xFFFF	
Off 1		0xFFFF	
Off 2		0xFFFF	
Off 3		0xFFFF	

Title	Options	Default/bit range	Description
Off 4		0xFFFF	
Off 5		0xFFFF	

3.6.2.9 15.4 RCU FEM Rx control

Tag number: 18

Length: 24

Title	Options	Default/bit range	Description
15.4 RCU FEM Rx Control (byte 0-23)		0xFF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF	This tag contains the front-end module controls for assertion logic during 15.4 Receive operations.
On 0		0xFFFF	
On 1		0xFFFF	
On 2		0xFFFF	
On 3		0xFFFF	
On 4		0xFFFF	
On 5		0xFFFF	
Off 0		0xFFFF	
Off 1		0xFFFF	
Off 2		0xFFFF	
Off 3		0xFFFF	
Off 4		0xFFFF	
Off 5		0xFFFF	

3.6.3 Coexistence NVM parameters list

NVM parameters are grouped into tags. The format and length of the NVM parameters are different for each tag. The minimum length is one byte. Common NVM tags are latched on the first HCI or MLME reset and applied globally. The little-endian tag format places the least significant byte (LSB) at the first position of the tag and the most significant byte (MSB) at the last position of the tag.

Tag Number	Name	Length (byte)
101	Coexistence Configuration	14
102	External PTA Configuration	6
103	Priority Configuration	15
104	Threshold Configuration	18

3.6.3.1 Coexistence configuration

Tag number: 101

Length: 14

Title	Options	Default/bit range	Description
Config Flags		0xE1 01 00 00	This tag contains the flags for coexistence configuration. The values are defined as: COEX_CONFIG_FLAG_COEX_ENABLE 0x00000001 COEX_CONFIG_FLAG_EPTA_ENABLE 0x00000002 COEX_CONFIG_FLAG_EPTA_MASTER 0x00000004 COEX_CONFIG_FLAG_WLAN_ENABLE 0x00000008 All other bits are reserved by the system and must remain their default values.
Grant Delay Timer		Default: 0x02	Delay between stomping one radio and granting another.
WLAN Antenna		Default: 0x00	Antenna number used for WLAN
BLE Antenna		Default: 0x01	Antenna number used for BLE
802.15.4 Antenna		Default: 0x01	Antenna number used for 802.15.4
WLAN Channel Width		Default: 0x14	WLAN channel width.
BLE Channel Width		Default: 0x02	BLE channel width.
802.15.4 Channel Width		Default: 0x05	802.15.4 channel width.
Overlap Disable		Default: 0x00	Disabled frequency overlap. Bit 0 indicates 802.15.4 does not overlap BLE or WLAN Bit 1 indicates BLE does not overlap WLAN or 802.15.4 Bit 2 indicates WLAN does not overlap BLE or 802.15.4
Concurrency		Default: 0x00	Enables/disables concurrency control. Bit 0 indicates Rx/Tx concurrency control is enabled Bit 1 indicates Tx/Tx concurrency control is enabled Bit 2 indicates Rx/Rx concurrency control is enabled

3.6.3.2 External PTA configuration

Tag number: 102

Length: 6

Title	Options	Default/bit range	Description
Grant Delay Enable		0x00	Enables grant delay on external PTA interface.
Priority Window Timer		0x09	Timer value for the priority window.
A2DP Done Timer		0x14	A2DP done timer value.
A2DP Done Timer Enable		0x00	A2DP done timer enable (1) or disable (0).
T15		0x07	Interface T15 value.
T16		0x05	Interface T16 value.

3.6.3.3 Priority configuration

Tag number: 103

Length: 15

Title	Options	Default/bit range	Description
EPTA_PRI_REQ_HIGH		0x12	Priority used when a high priority external PTA request is made.
EPTA_PRI_REQ_LOW		0x0A	Priority used when a low priority external PTA request is made.
EPTA_PRI_ACTIVE_HIGH		0x3B	Priority used once a high priority external PTA request is granted.
EPTA_PRI_ACTIVE_LOW		0x2C	Priority used once a low priority external PTA request is granted.
I15P4_PRI_TX_REQ		0x2A	Priority used when an 802.15.4 Tx request is made.
I15P4_PRI_RX_REQ		0x2B	Priority used when an 802.15.4 Rx request is made.
I15P4_PRI_TX_ACTIVE		0x39	Priority used when an 802.15.4 Tx transaction is granted.
I15P4_PRI_RX_ACTIVE		0x3A	Priority used when an 802.15.4 Rx transaction is granted.
I15P4_PRI_HOLD_REQ		0x38	Priority used to hold 802.15.4 grant between back to back transactions.
I15P4_PRI_ED_SCAN		0x29	Priority to use for an 802.15.4 ED scan.
I15P4_PRI_ACK		0x3C	Priority to use for an 802.15.4 ACK.
BLE_PRI_ADV		0x14	Priority to use for a Bluetooth LE advertisement.
BLE_PRI_SCAN		0x13	Priority to use for a Bluetooth LE scan.
BLE_PRI_DATA_REQ		0x15	Priority used when a Bluetooth LE data transaction is requested.
BLE_PRI_DATA_ACTIVE		0x2D	Priority used when a Bluetooth LE data transaction is granted.

3.6.3.4 Threshold configuration

Tag number: 104

Length: 18

Title	Options	Default/bit range	Description
Flags		0x00 00	Bit 0 enables (1) or disables (0) priority threshold.
BLE Scan Config		0x00 00	BLE scan threshold: Bits 14-15: Mode, 0 for counter-based, 3 for timer-based Bits 7-13: Value to use for hold threshold. Bits 0-6: Value to use for stomp threshold.
BLE Adv Config		0x00 00	BLE advertise threshold: Bits 14-15: Mode, 0 for counter-based,3 for timer-based Bits 7-13: Value to use for hold threshold. Bits 0-6: Value to use for stomp threshold.
BLE Data Config		0x00 00	BLE data threshold: Bits 14-15: Mode, 0 for counter-based, 3 for timer-based Bits 7-13: Value to use for hold threshold. Bits 0-6: Value to use for stomp threshold.
BLE Isoc Config		0x00 00	BLE isochronous threshold: Bits 14-15: Mode, 0 for counter-based,3 for timer-based Bits 7-13: Value to use for hold threshold. Bits 0-6: Value to use for stomp threshold.
802.15.4 ED Scan Config		0x00 00	802.15.4 ED scan threshold: Bits 14-15: Mode, 0 for counter-based,3 for timer-based Bits 7-13: Value to use for hold threshold. Bits 0-6: Value to use for stomp threshold.
802.15.4 beacon Scan Config		0x00 00	802.15.4 beacon scan threshold: Bits 14-15: Mode, 0 for counter-based,3 for timer-based Bits 7-13: Value to use for hold threshold. Bits 0-6: Value to use for stomp threshold.
802.15.4 Data Rx Config		0x00 00	802.15.4 data Rx threshold: Bits 14-15: Mode, 0 for counter-based, 3 for timer-based Bits 7-13: Value to use for hold threshold. Bits 0-6: Value to use for stomp threshold.
802.15.4 Data Tx Config		0x00 00	802.15.4 data Tx threshold: Bits 14-15: Mode, 0 for counter-based, 3 for timer-based Bits 7-13: Value to use for hold threshold. Bits 0-6: Value to use for stomp threshold.

3.6.4 Common NVM parameters list

NVM parameters are grouped into tags. The format and length of the NVM parameters are different for each tag. The minimum length is one byte. common NVM tags are latched on the first HCI or MLME reset, and are applied globally. The little-endian tag format places the least significant byte (LSB) at the first position of the tag and the most significant byte (MSB) at the last position of the tag.

Tag Number	Name	Length (byte)
190	FEM Control	6

3.6.4.1 FEM control

Tag number: 190

Length: 6

Title	Options	Default/bit range	Description
FEM Control		0x00 00 00 00 00 00	This tag contains the Front-End Module controls for assertion logic that is shared between technologies.
FEM Control 0 (byte 0)		Default: 0x00	
FEM Control 1 (byte 1)		Default: 0x00	
FEM Control 2 (byte 2)		Default: 0x00	
FEM Control 3 (byte 3)		Default: 0x00	
FEM Control 4 (byte 4)		Default: 0x00	
FEM Control 5 (byte 5)		Default: 0x00	

3.7 Firmware upgrade

QCA402x provides a flexible and modular firmware upgrade feature. The upgrade framework is based on plug-ins for different transport protocols and is agnostic to the interface used. An example is an the upgrade that can occur over the air using FTP running over the WLAN interface.

Sample FTP and HTTP plug-ins are provided in the SDK. CLI commands to test firmware upgrade operation are described in the *Firmware upgrade* section of *QCA402x Development Kit User Guide* (80-YA121-140).

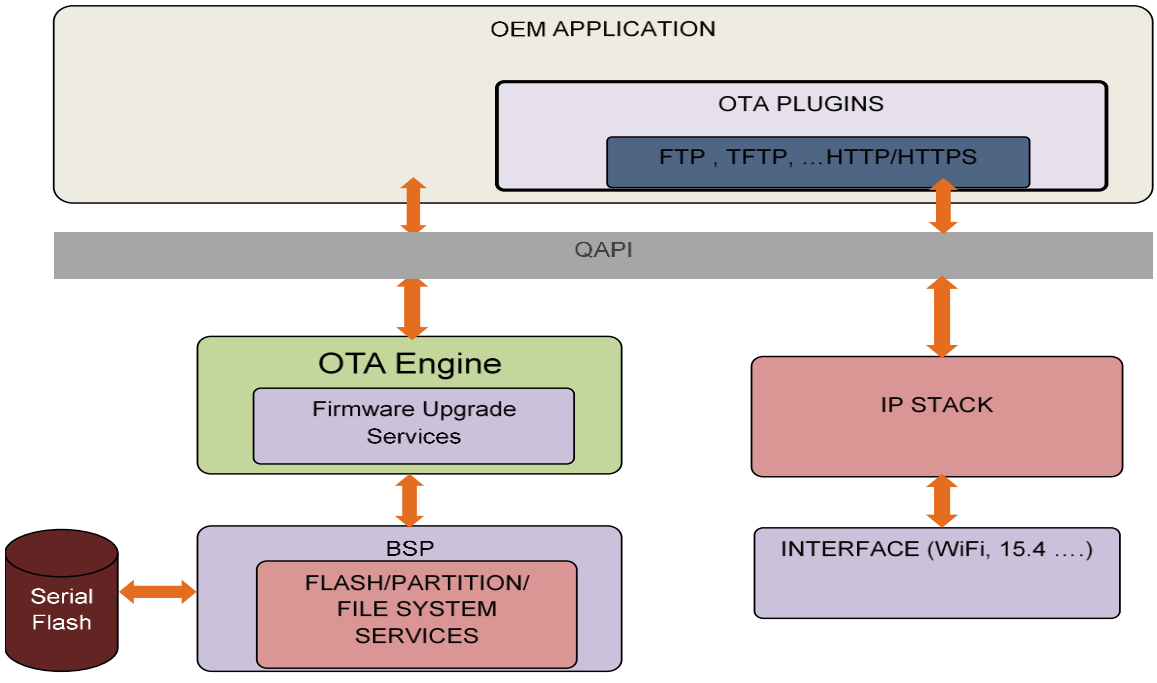


Figure 3-3 QCA402x firmware upgrade framework

3.7.1 Firmware upgrade overview

At the core of the firmware upgrade mechanism are the concept of "current" and "trial" image sets in flash. A "current" or "active" image set holds the image currently running on the device. A "trial" image set is used to store images that are downloaded during firmware upgrade. Optionally, there is provision for "golden" image set, which can be used to store factory-reset images.

The following steps provide a high-level overview of firmware upgrade procedure:

- Application triggers firmware upgrade by invoking upgrade QAPI. Connection and plug-in parameters are passed via the API.
- The upgrade plug-in initiates a connection to upgrade server and download the config file. This file provides information about the number of sub-images, image size, and hash values.
- Based on the config information, other images are downloaded, validated, and written to a "trial" partition. If images are written successfully, the "trial "is marked as valid and a system reset is triggered.
- The primary boot loader, after detecting the presence of "trial" image set, loads the newly downloaded images.
- The application might now choose to run some tests before confirming the success or failure of the upgrade.
- If the upgrade is successful, the "trial" images are marked as current. All subsequent reboots now load the new set of "current" images.
- If upgrade is a failure, the "trial" image is marked as invalid and a subsequent reboot loads the last known set of "current" images.

3.7.2 Firmware upgrade image set

A typical image set for QCA402x firmware upgrade contains the following images:

- Firmware Upgrade Config file.
- Application Image (runs on Cortex-M4F, generated by OEM)
- Narrowband Image (Runs on Cortex-M0, provided by Qualcomm)
- WLAN image (provided by Qualcomm)
- File-System binary (generated by OEM)

If the RAM dump stored in flash memory is supported, a RAM dump pattern image is mandatory which is 500 KB prefilled with 0xFF to reserve the partition.

3.7.3 Supported flash configurations

The supported flash configurations are:

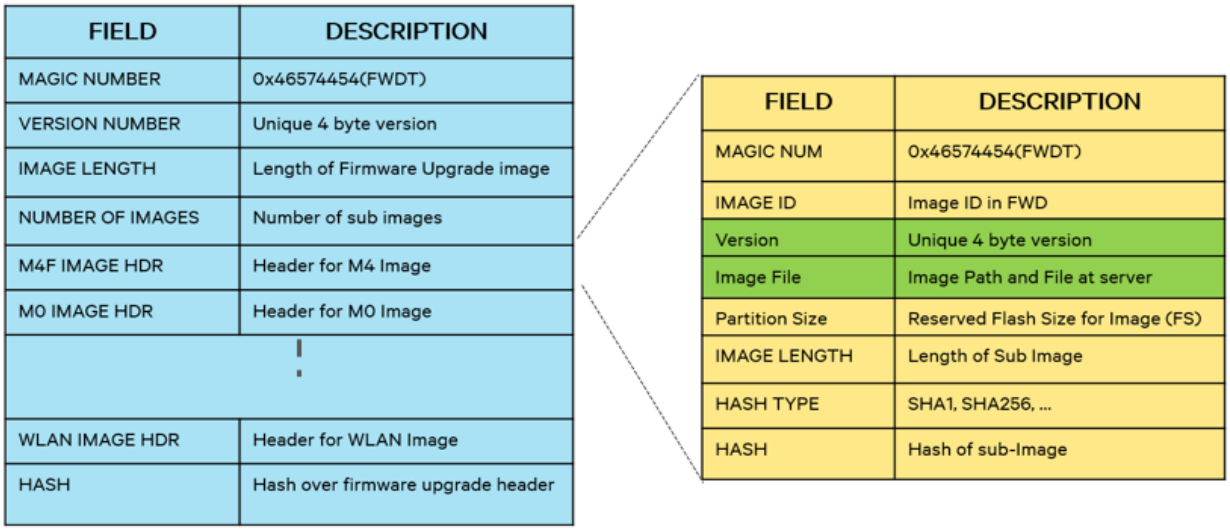
- Current + Trial Image Sets – This image set follows the ping-pong approach. The trial region holds the newly downloaded images. After the upgrade is validated, trial becomes the new current. This is the minimal configuration required to perform firmware upgrade.

- Golden + Current + Trial Image Sets – An Optional scenario where a Golden image set is used to hold a back-up image. Golden image set cannot be overwritten during a firmware upgrade.

3.7.4 Configuration file

The configuration file contains all the metadata required by the upgrade engine to perform a successful upgrade. The SDK contains image generation tools that allow an OEM to generate the config file based on their requirements. shows the format of the config file.

NOTE: Version number is a 4- byte field that is managed by the OEM. This value is stored in flash during firmware upgrade and can be retrieved by the application using a QAPI.



FIELD	DESCRIPTION
MAGIC NUMBER	0x46574454(FWDT)
VERSION NUMBER	Unique 4 byte version
IMAGE LENGTH	Length of Firmware Upgrade image
NUMBER OF IMAGES	Number of sub images
M4F IMAGE HDR	Header for M4 Image
M0 IMAGE HDR	Header for M0 Image
WLAN IMAGE HDR	Header for WLAN Image
HASH	Hash over firmware upgrade header

FIELD	DESCRIPTION
MAGIC NUM	0x46574454(FWDT)
IMAGE ID	Image ID in FWD
Version	Unique 4 byte version
Image File	Image Path and File at server
Partition Size	Reserved Flash Size for Image (FS)
IMAGE LENGTH	Length of Sub Image
HASH TYPE	SHA1, SHA256, ...
HASH	Hash of sub-Image

Figure 3-4 QCA402x firmware upgrade config file format

3.7.5 Support for partial upgrade

An OEM can optionally choose to upgrade a subset of images instead of the entire image set. Consider scenario sample scenario where OEM made a critical fix in the application image, but no changes were made to other images. The image set then consists of config file and application image.

To re-create the complete image set, the upgrade engine can copy missing images from the current partition to trial partition. The engine can also identify the subimages that have changed since the last upgrade (by comparing the hash values) and then selectively download them.

3.7.6 Support for full upgrade

An OEM can optionally choose to upgrade the entire image- set. The upgrade engine copies the entire image-set to trial partition in a single combined file.

3.7.7 Firmware upgrade image generation tool

The SDK includes Python- based tools for generating Firmware Upgrade image. The tool is available at: `target\build\tools\fwupgrade\gen_fw_upgrade_img.py`

The tool reads an XML configuration file for input parameters. A sample XML file is available at `target\build\tools\fwupgrade\fw_upgrade.xml`

The XML file contains information on different images that are included in the combined upgrade image. Different parameters in the XML file are as follows:

- "filename": Indicates path to an image binary/elf. The path must be same path at fw_upgrade server.
- "image_id": An identifier that is associated with each image and must not be modified. The possible values are:

5: File-system binary (optional)

10: Cortex-m4f image (OEM application image)

11: Cortex-M0 image

13: WLAN firmware image (only valid on QCA4020)

A sample XML file running QCLI demo with ThreadX is as follows:

```
<?xml version="1.0" ?>
<fw_upgrade_img_descriptor>
      <!-- format: 1: partial upgrade, 2: full upgrade in one file -->
      <header signature="0x54445746" version="1"/>
      <partition filename="" signature="0x54445746" image_id="5" ver=”1”
size_in_kb="64" HASH_TYPE="1"/>
      <partition filename="Quartz_HASHED.elf" signature="0x54445746"
image_id="10" ver=”1” size_in_kb="0" HASH_TYPE="1"/>
      <partition filename="ioe_ram_m0_threadx_ipt.mbn"
signature="0x54445746" image_id="11" ver=”1” size_in_kb="0"
HASH_TYPE="1"/>
      <partition filename="wlan_fw_img.bin" signature="0x54445746"
image_id="13" ver=”1” size_in_kb="0" HASH_TYPE="1"/>
</fw_upgrade_img_descriptor>
```

"size_in_kb": Non-zero value is used to reserve space for an image (for example, File system). When this is set to zero, the size is calculated from the image file.

OEMs can edit this file to indicate location of application image.

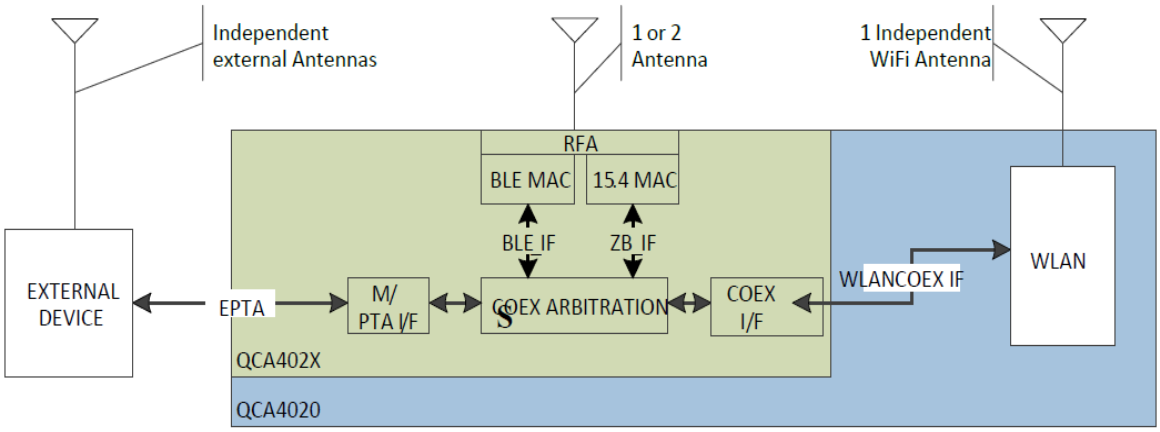
The following command generates a combined firmware upgrade image called 'ota.bin'.

```
python gen_fw_upgrade_img.py --xml fw_upgrade.xml --output ota.bin
```

- ota.bin and all files which are listed at fw_upgrade.xml are needed to be copied to firmware upgrade server for firmware upgrade when "format" in fw_upgrade.xml is set to "1".
- ota.bin is needed to be copied to firmware upgrade server for firmware upgrade when "format" at firmware upgrade.xml setting is "2." The file includes config file and all files listed at fw_upgrade.xml.

3.8 WLAN coexistence usage notes

The QCA4020 WLAN subsystem is designed to coexist with both the on-chip BLE/15.4 technologies and off-chip Bluetooth Classic technologies via the external PTA (EPTA) interface pins of the chip.



The WLAN coexistence subsystem supports simultaneous on-chip BLE and/or 15.4 combined with a single Bluetooth Classic profile on the EPTA interface. When a profile is enabled, it is important to specify the appropriate mode for which it needs to be enabled:

- qapi_WLAN_Coex_Config_Data_t.coex_Mode = QAPI_WLAN_COEX_3_WIRE_MODE_E for on-chip technologies BLE or 15.4
- qapi_WLAN_Coex_Config_Data_t.coex_Mode = QAPI_WLAN_COEX_EPTA_MODE_E for EPTA-connected Bluetooth Classic technologies

After it is applied, coex profiles remain in effect over wake/sleep cycles. However, if the WLAN subsystem is explicitly disabled, it is necessary for the application to enable the appropriate WLAN coex profiles upon WLAN enable.

The qapi_WLAN_Coex_Sco_Config, qapi_WLAN_Coex_A2dp_Config, qapi_WLAN_Coex_Acl_Config, qapi_WLAN_Coex_InqPage_Config, qapi_WLAN_Coex_Hid_Config, and qapi_WLAN_Coex_Override_Wghts are advanced use APIs available when the WLAN coex performance requires fine-tuning. Common use cases do not require the invocation of these APIs. In most cases, the application must invoke the qapi_WLAN_Coex_Control API to enable or disable profiles appropriately.

3.8.1 Profile usage

- The application must enable the QAPI_BT_PROFILE_SCAN profile when it performs narrowband scans and during connection. The QAPI_BT_PROFILE_SCAN profile must be disabled immediately after a narrowband connect.
- QAPI_BT_PROFILE_LE must be used with the on-chip BLE and 15.4 technologies. coex_Mode must be set to QAPI_WLAN_COEX_3_WIRE_MODE_E.
- QAPI_BT_PROFILE_SCO, QAPI_BT_PROFILE_A2DP, QAPI_BT_PROFILE_ESCO, and QAPI_BT_PROFILE_HID are Bluetooth Classic technologies. So, coex_Mode must be set to QAPI_WLAN_COEX_EPTA_MODE_E for those profiles.

3.9 Network services

The Network services subsystem provides a rich set of QAPIs that enable basic Dual IP network communication, Secure Socket Layer (SSL) for transport layer security, and built-in implementation for advanced and common networking services.

3.9.1 BSD-Socket interface

The BSD-Socket QAPI is a collection of standard functions that allow the application to include Internet communication capabilities. In general, the BSD-Socket interface relies on client-server architecture and uses a socket object for every operation.

The interface supports TCP and UDP, server mode and client mode, and IPv4 and IPv6 communication.

A socket can be configured with specific options (See socket options as follows).

Due to the memory–constrained properties of the device, it is mandatory to follow the BSD-socket programming guidelines and check for return values of each function. There is a chance that an operation may fail due to resource limitations.

Example: The send function might be able to send only some of the data and not all of it in a single call. A consequent call with the rest of the data is required. In some other cases, an application thread might need to sleep to allow the system to clear/drain its queues, and process data.

3.9.1.1 Setting up a socket

To start a communication session, it is required to create a socket using the `qapi_socket` QAPI, which requires involves three parameters:

- Domain: Configures the socket to use either IPv4 protocol (AF_INET) or IPv6 protocol (AF_INET6). It is not possible to share the same socket for both protocols.
- Type: Configures the transport layer for the socket. The supported options are TCP (SOCK_STREAM), UDP (SOCK_DGRAM) or Raw (SOCK_RAW) which has a user-defined transport layer.
- Proto: Not used and must be zero.

Upon a successful socket creation, a socket handle is returned, or -1 in case of an error. The total number of sockets in the system is predefined in the device configuration parameters and the default value is 12.

After the communication is completed, or if a fatal error is returned by the send or receive functions, it is required to close the socket using the `qapi_socketclose` QAPI.

3.9.1.2 Configure socket options

Socket options can be configured at various protocol levels. The supported levels are Socket level (SOL_SOCKET), IP level (IPPROTO_IP), and IP options to be sent with every packet on the socket (IP_OPTIONS). See qapi_socket.h for a full list of options. The socket options are generic and might vary in size. Therefore, the call must specify the exact level, option, option value, and option size in bytes. The most common options are SO_NBIO to use a non-blocking socket, SO_KEEPALIVE to enable TCP keepalive option and SO_CALLBACK to enable zero-copy.

3.9.1.3 Establish a connection

A connection is established between two peers in TCP mode only. UDP is a connection-less protocol. However, the connection QAPIs can be still used to setup peer communication details, except for listen and accept commands which are not needed.

Furthermore, there are two basic scenarios where connections are established:

- The device is a server that accepts remote connections and does not initiate a connection.
- The device is a client that initiates a connection to a remote server.

NOTE: An application can perform any of these functionalities in parallel.

When operating in server mode, it is required to bind the socket to an address which is composed of the local IP address and a port on which the socket listens on. This configuration is set up using the `struct sockaddr_in` for IPv4 communication and `struct sockaddr_in6` for IPv6 communication. This structure must be initialized with the domain, IP address, and port number. Use `htons` function to convert the port number to Network order. It is possible to provide a zero for address and port. If the address is not specified, the system can use any address. If port is not specified, it uses a random port (not recommended, a server port needs to be well known). The configuration must be passed to `qapi_bind` QAPI.

The second step is to listen to incoming connection using `qapi_listen` QAPI. The backlog parameter configures the size of the pending connections queue. It is recommended to use zero or a low value in a memory-constrained system. A value of zero allows one pending connection and the second connection is refused.

The last step is to accept a connection using `qapi_accept` QAPI. This function returns a new socket which represents the foreign (or peer) socket after establishing a connection with a remote client. The function also provides the address details of the peer. For blocking mode sockets, this function blocks (indefinitely) until a connection is established.

For non-blocking sockets, the call always returns immediately, irrespective of the establishment of the connection. For the former, a socket is returned and for the latter, -1 is returned, with error code of EWOULDBLOCK.

When operating in client mode, it is required to configure the server (remote) address in the `struct sockaddr_in` for IPv4 communication and `struct sockaddr_in6` for IPv6 communication and use `qapi_connect` QAPI. If the connection is established, the function returns zero, otherwise it returns -1.

3.9.1.4 Receive data from a socket

Receiving data from a socket can be done by calling `qapi_recv` for connected (TCP) sockets, and `qapi_recvfrom` for connection-less (UDP) sockets. The caller provides a buffer to be used to copy the incoming data and its length in bytes. TCP sockets hold stream data internally until all data has been read by the application, thus calling the receive function with a buffer smaller than the queued data in the socket. Therefore, data loss is not caused. However, in UDP sockets which use datagrams, any unread bytes in a datagram are discarded. Therefore, the buffer must be significant enough for the anticipated data size or MTU.

The receive from function for UDP sockets also provides the peer (remote) address of the sender because UDP packets can be sent from any host.

Before calling the receive functions, it is possible to check for pending data in the socket. Using the `qapi_fd_set_t` type and the file descriptor QAPIs (`qapi_fd_xxx`), it is possible to add sockets which the application is interested to query and call `qapi_select` function. The select function checks for activity in the sockets specified in the set, during a specified timeout in milliseconds (or indefinitely). If there is an activity in one socket or more, the function returns the number of sockets with an event. If the function returns with a 0, it means that no event has occurred during the specified timeout. The application can then use `qapi_fd_isset` to figure out the socket that had any activity and then call the receive function with the appropriate socket handle.

An application that cannot block can specify 0 as timeout. This provides an immediate indication if there is any socket in the set that has an activity.

Zero-copy mode does not use the method to receive data. See section 3.9.1.7.

3.9.1.5 Send data to a socket

Sending data to a socket can be done by calling `qapi_send` for connected (TCP) sockets and `qapi_sendto` (with peer address) for connection-less (UDP) sockets. The caller needs to provide an application buffer with the data to be sent and its length in bytes.

The send function returns the number of bytes sent, or -1 in case of an error, which can be either a fatal error (permanent issue) or non-fatal error, such as ENOBUFS, EAGAIN or EWOULDBLOCK for non-blocking sockets. Non-fatal errors happen due to temporary internal network buffer shortage or unavailability. In this case, it is required that the application would yield the CPU to allow other tasks to drain their queues. In case, the application both sends and receives, the input queue needs to be drained first.

TCP sockets may be able to send all or some of the data in the buffer. There is no limit on the output buffer size, although the send may return a lower number of bytes sent. The caller must check the return value and call the send function again from the correct offset.

After all bytes have been confirmed to be sent, the application can reuse the same buffer or free it. This is not true in Zero-copy mode. For more information, see section 3.9.1.7.

3.9.1.6 Multicast

The device can be configured to receive multicast traffic (Join a Group) or to send multicast traffic.

To join a group, use the `struct ip_mreq` to configure an IPv4 Multicast group, or `struct ip_mreq6` to configure an IPv6 Multicast group. Call the set socket option function with IPPROTO_IP level, and IP_ADDMEMBERSHIP or IPV6_JOIN_GROUP accordingly. It is mandatory to specify the interface (or scope ID) that is used to receive the traffic.

To send multicast traffic, it is mandatory to specify the interface (or scope ID) that is used to send the traffic, and recommended to set hops, and disable loopback using the `IP_MULTICAST_TTL/ IPV6_MULTICAST_HOPS` and `IP_MULTICAST_LOOP/IPV6_MULTICAST_LOOP`.

3.9.1.7 Zero-copy interface

The Zero-copy interface allows the application to use and share system network buffers for sending and receiving data. This interface might reduce memory requirements and copy-operations that take place between the system and the application. In this mode, the application allocates a network buffer that can be chained to send data and receive is done via a callback mechanism, instead of the traditional select/recv way. The mechanism can be enabled by calling qapi_setsockopt() with option 'level' being `SOL_SOCKET or IPPROTO_IP` and 'optname' being `SO_CALLBACK` (for TCP) or `SO_UDPCALLBACK` (for UDP).

For example,

To enable TCP zero-copy:

```
qapi_setsockopt(handle, IPPROTO_IP, SO_CALLBACK, (void *)tcp_rx_callback,
0);
```

To enable UDP zero-copy:

```
qapi_setsockopt(handle, IPPROTO_IP, SO_UDPCALLBACK, (void
*)udp_rx_callback, 0);
```

where 'handle' is the socket handle returned from qapi_socket(). 'tcp_rx_callback' and 'udp_rx_callback' are callback functions called from the stack to inform the application of received data packets.

The callback functions must conform to the following prototype:

```
int32_t (*)(void *so, void *pkt, int32_t errcode) tcp_rx_callback;
int32_t (*)(void *so, void *pkt, int32_t errcode, void *from, int32_t
family) udp_rx_callback;
```

where 'so' is a pointer to an internal socket object, 'pkt' is a pointer to a system buffer (qapi_Net_Buf_t) containing received data for the socket if it is not NULL.

`((qapi_Net_Buf_t *)pkt)->nb_prot` points to the start of the received data

`((qapi_Net_Buf_t *)pkt)->nb_plen` indicates the number of bytes of received data in the buffer.

The amount of data in the buffer chain is available in ((qapi_Net_Buf_t *)pkt)->nb_tlen field of the first buffer in the chain. 'errcode' is used by the stack to report some events. If it is not 0, it is a socket error indicating that an error or other event has occurred on the socket.
For TCP, typical non-zero values are ESHUTDOWN, indicating that the connected peer has closed its end of the connection and sends no more data ECONNRESET indicates that the connected peer has abruptly closed its end of the connection and neither sends nor receives more data. 'from' is a pointer to struct sockaddr_in if 'family' is AF_INET or to struct sockaddr_in6 if 'family' is AF_INET6. 'from' indicates the sender of received data.

If the callback function returns 0, it indicates that the connected peer has accepted responsibility for the system buffer and returns it to the stack (via call to qapi_Net_Buf_Free(pkt, QAPI_NETBUF_SYS)) when it no longer needs the buffer. If the callback function returns any non-zero value, it indicates to the stack that the connected peer has not accepted responsibility for the system buffer.

3.9.2 Acquire an IP address

The or IP address is a unique address used to identify hosts and communicate with other hosts in the IP network. Any device connected to the IP network must have a unique IP address within the network. There are multiple options to set or acquire an IP address.

3.9.2.1 IPv4 auto-configuration / link local addresses

IPv4 Link-local address is in the range of 169.254.0.0/16 and is valid only for communications within the network link (or the broadcast domain) that the host is connected to. Link local addresses are not guaranteed to be unique beyond a single network link but are guaranteed to be unique within it.

Link local addresses are used in a network that has no DHCPv4 server. There is no managed/centralized way to acquire a valid IPv4 address.

To generate a unique link local address, the application needs to use the IP configuration QAPI `qapi_Net_IPv4_Config` and the QAPI_NET_IPV4CFG_AUTO_IP_E option.

3.9.2.2 Static IPv4 address

An interface can be configured with a static IPv4 address, which is normally used when the device is in router with QCMobileAP mode (along with DHCPv4 server service).

To generate a unique link local address, the application needs to use the IP configuration QAPI, `qapi_Net_IPv4_Config` and use the QAPI_NET_IPV4CFG_STATIC_IP_E option.

3.9.2.3 DHCPv4 client

The system supports automatic acquisition of an IPv4 address using DHCPv4 client. For more information, see network services.

3.9.2.4 IPv6 link local addresses

IPv6 Link local address, normally in the range of fe80::/64, is reserved for link local unicast addressing. Unlike IPv4, IPv6 requires a link local address on every interface which results in multiple concurrent addresses for each interface. The IPv6 link local address is automatically generated by the system.

3.9.2.5 IPv6 global address

A host uses an IPv6 global address to communicate with remote hosts in the Internet outside the local link. The IPv6 global address is automatically acquired by the system if there is an IPv6 router in the network (through neighbor discovery protocol and router solicitation message).

The device can also acquire IPv6 global address using DHCPv6 client. For more information, see network services.

3.9.3 Net buffers and profiles

When an application invokes `qapi_send()` to send data to the network, the application data is copied into a net buffer. Similarly, when data is received, and application invokes `qapi_recv()`, the data received is copied from Net buffer to application buffer.

So, a Net buffer holds either a single packet or a chain of packets that are intended to be transmitted or received at any time. A netbuffer is represented by `qapi_Net_Buf_t`.

Netbuffers can be of varying sizes. By default, QCA420x supports a free netbuffer pool containing *128*, *512*, and *1536* buffer sizes. This free pool serves a netbuffer allocation request. If there are no netbuffers available, then the allocation might fail.

The free netbuffer pool is configurable using profiles at runtime. The M4 on QCA420x supports three preset net profiles and a custom profile. The preset profiles are:

- *Performance*: This profile must be used when performance is a priority. This requires more memory.
- *Best Effort:* This profile balances performance and memory.
- *Memory optimized*: This profile is optimized for memory and hence results in reduced performance.

The default profile is *Best Effort*.

To switch between preset profiles, use the following QAPI:

```
qapi_Status_t qapi_Net_Profile_Set_Active(qapi_Net_Profile_Type_t profile);
```

To create a custom profile, use the following QAPI:

```
qapi_Status_t qapi_Net_Profile_Set_Custom(qapi_Net_Profile_Custom_Pool_t
*pNet_buf, uint8_t net_bufq_size);
```

A user must choose a net profile that meets the application requirement. When switching to a custom profile using the QAPI, the application should specify the number of netbuffer pools (`net_bufq_size`) and a pointer `pNet_buf` containing the size of netbuffers in each pool and number of netbuffers in that pool.

For example, A custom profile can be `net_bufq_size` = 3 and `pNet_buf` could point to an array [128 5 512 4 1536 5]. Switching between profiles is not allowed when there are open sockets in the system. The return status `QAPI_ERR_BUSY` indicates that there are open sockets.

For other error values, refer to *QCA402x QAPI specification* (80-Y9381-7).

3.9.4 SSL

The Secure Socket Layer (SSL) interface provides authentication, privacy (encryption), and data integrity between two peers communicating over TCP or UDP. After a connection is established, the two peers use a handshake mechanism to authenticate and establish the keys used for encryption/decryption and data verification. After the handshake is successful, data can be securely transmitted or received over the SSL connection.

3.9.4.1 Protocol versions

The supported protocols are: TLS1.0, TLS1.1, TLS1.2 (over TCP) and DTLS1.0, DTLS1.2 (over UDP). The application can select to enable a specific protocol using the `qapi_Net_SSL_Configure` QAPI or allow the handshake to select automatically.

SSLv3 support has been deprecated due to security vulnerabilities.

3.9.4.2 Modes of operation

The two modes of operations are:

- Server mode: The device waits for incoming connection and participates as the server role in the handshake.
- Client mode: The device initiates a connection to a remote server and participates as the client role in the handshake.

3.9.4.3 Supported cipher suites

The following cipher suites are supported:

- TLS_PSK_WITH_AES_256_GCM_SHA384 (0x00a9)
- TLS_PSK_WITH_AES_256_CBC_SHA384 (0x00af)
- TLS_PSK_WITH_AES_256_CBC_SHA (0x008d)
- TLS_ECDHE_PSK_WITH_AES_128_CBC_SHA256 (0xc037)
- TLS_PSK_WITH_AES_128_GCM_SHA256 (0x00a8)
- TLS_PSK_WITH_AES_128_CBC_SHA256 (0x00ae)
- TLS_PSK_WITH_AES_128_CBC_SHA (0x008c)
- TLS_PSK_WITH_AES_128_CCM_8 (0xc0a8)
- TLS_ECDHE_ECDSA_WITH_AES_256_GCM_SHA384 (0xc02c)
- TLS_ECDHE_ECDSA_WITH_AES_256_CBC_SHA384 (0xc024)
- TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256 (0xc02b)
- TLS_ECDHE_ECDSA_WITH_AES_128_CBC_SHA256 (0xc023)
- TLS_ECDHE_ECDSA_WITH_AES_256_CBC_SHA (0xc00a)
- TLS_ECDHE_ECDSA_WITH_AES_128_CBC_SHA (0xc009)
- TLS_ECDH_ECDSA_WITH_AES_256_GCM_SHA384 (0xc02e)
- TLS_ECDH_ECDSA_WITH_AES_256_CBC_SHA384 (0xc026)
- TLS_ECDH_ECDSA_WITH_AES_128_GCM_SHA256 (0xc02d)
- TLS_ECDH_ECDSA_WITH_AES_128_CBC_SHA256 (0xc025)
- TLS_ECDH_ECDSA_WITH_AES_256_CBC_SHA (0xc005)
- TLS_ECDH_ECDSA_WITH_AES_128_CBC_SHA (0xc004)
- TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384 (0xc030)
- TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA384 (0xc028)
- TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256 (0xc02f)
- TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA256 (0xc027)
- TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA (0xc014)
- TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA (0xc013)
- TLS_ECDH_RSA_WITH_AES_256_GCM_SHA384 (0xc032)

- TLS_ECDH_RSA_WITH_AES_256_CBC_SHA384 (0xc02a)
- TLS_ECDH_RSA_WITH_AES_128_GCM_SHA256 (0xc031)
- TLS_ECDH_RSA_WITH_AES_128_CBC_SHA256 (0xc029)
- TLS_ECDH_RSA_WITH_AES_256_CBC_SHA (0xc00f)
- TLS_ECDH_RSA_WITH_AES_128_CBC_SHA (0xc00e)
- TLS_DHE_RSA_WITH_AES_256_GCM_SHA384 (0x009f)
- TLS_DHE_RSA_WITH_AES_256_CCM (0xc09f)
- TLS_DHE_RSA_WITH_AES_256_CCM_8 (0xc0a3)
- TLS_DHE_RSA_WITH_AES_256_CBC_SHA256 (0x006b)
- TLS_DHE_RSA_WITH_AES_256_CBC_SHA (0x0039)
- TLS_DHE_RSA_WITH_AES_128_GCM_SHA256 (0x009e)
- TLS_DHE_RSA_WITH_AES_128_CCM (0xc09e)
- TLS_DHE_RSA_WITH_AES_128_CCM_8 (0xc0a2)
- TLS_DHE_RSA_WITH_AES_128_CBC_SHA256 (0x0067)
- TLS_DHE_RSA_WITH_AES_128_CBC_SHA (0x0033)
- TLS_RSA_WITH_AES_256_GCM_SHA384 (0x009d)
- TLS_RSA_WITH_AES_256_CCM (0xc09d)
- TLS_RSA_WITH_AES_256_CCM_8 (0xc0a1)
- TLS_RSA_WITH_AES_256_CBC_SHA256 (0x003d)
- TLS_RSA_WITH_AES_256_CBC_SHA (0x0035)
- TLS_RSA_WITH_AES_128_GCM_SHA256 (0x009c)
- TLS_RSA_WITH_AES_128_CCM (0xc09c)
- TLS_RSA_WITH_AES_128_CCM_8 (0xc0a0)
- TLS_RSA_WITH_AES_128_CBC_SHA256 (0x003c)
- TLS_RSA_WITH_AES_128_CBC_SHA (0x002f)
- TLS_ECDHE_ECDSA_WITH_CHACHA20_POLY1305_SHA256 (0xcc14)
- TLS_ECDHE_RSA_WITH_CHACHA20_POLY1305_SHA256 (0xcc13)
- TLS_DHE_RSA_WITH_CHACHA20_POLY1305_SHA256 (0xcc15)
- TLS_ECJPAKE_WITH_AES_128_CCM_8 (0xc0ff)

The application can select to enable specific cipher suites using the `qapi_Net_SSL_Cipher_Add` and `qapi_Net_SSL_Configure` QAPIs or allow the handshake to select a cipher suite automatically.

3.9.4.4 Server authentication

During the connection to a remote server, as part of the TLS/DTLS handshake process, the local client can authenticate the server by processing the server certificate.

The authentication process includes:

- Domain/host name verification
- Certificate expiration date verification

Furthermore, to verify that the certificate is authentic, there is a need for a root of trust, or a third-party side that both the client and server trust. A certificate is usually signed by the root or by a chain of roots, where the client must trust one of them for the server certificate. To allow this process to happen, it is required to provision a Certificate Authority (CA) List file which contains details and public keys of CAs that the device can trust and load it to the corresponding SSL connection object using the `qapi_Net_SSL_Cert_Load` QAPI. The CA list file provisioning can be done as part of the production process or using the `qapi_Net_SSL_Cert_Store` QAPI in runtime.

The default setting is to skip all verifications and establish the connection. Therefore, it is highly recommended that the application in production mode enables server authentication using the `qapi_Net_SSL_Configure` QAPI.

3.9.4.5 Client authentication

During the connection to a remote server, as part of the TLS/DTLS handshake process, the remote server can optionally request the local client to authenticate to the server by requesting the client certificate. This process is similar to server authentication.

To allow this process to happen, it is required to provision a Certificate file which contains the device's public and private key pairs. The public key pair is signed by a root (CA) which is trusted by the server and loads it to the corresponding SSL connection object using the `qapi_Net_SSL_Cert_Load` QAPI. The certificate file provisioning can be done as part of the production process or using the `qapi_Net_SSL_Cert_Store` QAPI in runtime.

3.9.4.6 SNI

The Server name indication (SNI) transport layer security (TLS) extension allows the application to specify a host/server name to connect to as a part of the handshake process. It allows a server to support multiple secure services on the same IP address and port, and thus present the correct certificate to the client.

To configure SNI, use the `qapi_Net_SSL_Configure` QAPI.

3.9.4.7 ALPN

The Application layer protocol negotiation (ALPN) TLS extension allows the application to specify a protocol to be used after the secure connection is established (in client mode), or a list of supported protocols to offer the client (in server mode). This is done by calling the `qapi_Net_SSL_ALPN_Protocol_Add` QAPI.

In client mode, the connection is successful if the server supports the requested protocol or does not support ALPN extension. The connection fails if the client and server do not agree on a mutually supported protocol.

In server mode, the application can use the `qapi_Net_SSL_ALPN_Protocol_`Get or `qapi_Net_SSL_ALPN_Get_Protocol_For_Peer` QAPIs to get the protocol that was negotiated with the client.

3.9.4.8 SSL certificate manager

The SSL certificate manger is a software module responsible for storing and loading the certificates and CA lists from flash using secure storage. It contains the following API functions:

- `qapi_Net_SSL_Cert_Store()`: Stores the certificate or CA list into flash.
- `qapi_Net_SSL_Cert_Load()`: Loads the certificate or CA list from flash into the SSL object.
- `qapi_Net_SSL_Cert_List()`: Lists the certificates or CA lists stored in flash.
- `qapi_Net_SSL_Cert_Get_Hash()`: Creates a hash for the certificate or CA list stored in flash.
- `qapi_Net_SSL_Cert_Validate ()`: Validates a given certificate against a CA list stored in flash.
- `qapi_Net_SSL_Cert_Get_Expiration ()`: Gets the expiration details of a certificate stored in flash.
- `qapi_Net_SSL_PSK_Table_Set()`: Stores the pre-shared keys (PSK) table to be used with TLS PSK ciphers.
- `qapi_Net_PSK_Table_Clear()`: Clears the PSK table.

3.9.4.8.1 Storing certificates and CA lists securely in flash

The `qapi_Net_SSL_Cert_Store()` QAPI function is used to store both the certificates and the CA lists securely into the flash. It accepts certificates and CA lists in PEM format or proprietary binary format. When certificate or CA list in PEM format is passed to this function, it converts it into a proprietary binary format, and then stores this binary representation into the flash. When this function is used to store certificate in PEM format, the caller must also pass the private key in PEM format.

The certificates are stored in the flash using the Secure Storage running on TEE. Since TEE is used to store the certificates, only the TEE is able to access them. The private key stored with the certificate never leaves the TEE. Consequently, all operations that need to be performed with private key are performed inside TEE.

The CA lists are stored into the flash using Secure Storage running on host CPU since they do not contain private information. Since both the certificates and the CA lists are stored using secure storage, it is impossible to decrypt the stored certificates or CA lists using external flash reader.

The code snippets show how to store certificates and CA lists in both PEM and binary formats.

3.9.4.8.1.1 Store certificate and key in PEM format securely into flash using TEE secure storage

```
qapi_Net_SSL_Cert_Info_t cert_info;
memset(&cert_info, 0, sizeof(cert_info));
cert_info.cert_Type = QAPI_NET_SSL_PEM_CERTIFICATE_WITH_PEM_KEY_E;
cert_info.info.pem_Cert.cert_Buf = BUFFER_CONTAINING_PEM_CERTIFICATE;
```

```
cert_info.info.pem_Cert.cert_Size =
SIZE_OF_BUFFER_CONTAINING_PEM_CERTIFICATE;
cert_info.info.pem_Cert.key_Buf = BUFFER_CONTAINING_PEM_PRIVATE_KEY;
cert_info.info.pem_Cert.key_Size =
SIZE_OF_BUFFER_CONTAINING_PEM_PRIVATE_KEY;
char * name = CERTIFICATE_NAME_TO_STORE_ON_FLASH;
qapi_Status_t status = qapi_Net_SSL_Cert_Store(&cert_info, name);
```

3.9.4.8.1.2 Store certificate in binary format into flash using TEE secure storage

```
qapi_Net_SSL_Cert_Info_t cert_info;
memset(&cert_info, 0, sizeof(cert_info));
cert_info.cert_Type = QAPI_NET_SSL_BIN_CERTIFICATE_E;
cert_info.info.bin_Cert.cert_Buf = BUFFER_CONTAINING_BINARY_CERTIFICATE;
cert_info.info.bin_Cert.cert_Size =
SIZE_OF_BUFFER_CONTAINING_BINARY_CERTIFICATE;
char * name = CERTIFICATE_NAME_TO_STORE_ON_FLASH;
qapi_Status_t status = qapi_Net_SSL_Cert_Store(&cert_info, name);
```

3.9.4.8.1.3 Store CA list in PEM format into flash using secure storage

```
qapi_Net_SSL_Cert_Info_t cert_info;
memset(&cert_info, 0, sizeof(cert_info));
qapi_CA_Info_t ca_info;
ca_info.ca_Buf = BUFFER_CONTAINING_PEM_CA_LIST;
ca_info.ca_Size = SIZE_OF_BUFFER_CONTAINING_PEM_CA_LIST;
cert_info.cert_Type = QAPI_NET_SSL_PEM_CA_LIST_E;
cert_info.info.pem_CA_List.ca_Cnt = 1;
cert_info.info.pem_CA_List.ca_Info[0] = &ca_info;
char * name = CA_LIST_NAME_TO_STORE_ON_FLASH;
qapi_Status_t status = qapi_Net_SSL_Cert_Store(&cert_info, name);
```

3.9.4.8.1.4 Store Binary CA list into flash using secure storage

```
qapi_Net_SSL_Cert_Info_t cert_info;
memset(&cert_info, 0, sizeof(cert_info));
cert_info.cert_Type = QAPI_NET_SSL_BIN_CA_LIST_E;
cert_info.info.bin_CA_List.ca_List_Buf =
BUFFER_CONTAINING_BINARY_CA_LIST;
cert_info.info.bin_CA_List.ca_List_Size =
SIZE_OF_BUFFER_CONTAINING_BINARY_CA_LIST;
char * name = CA_LIST_NAME_TO_STORE_ON_FLASH;
qapi_Status_t status = qapi_Net_SSL_Cert_Store(&cert_info, name);
```

3.9.4.8.2 Load certificate or CA list from flash into SSL object

The `qapi_Net_SSL_Cert_Load()` QAPI function is used to load the certificate from flash and attaching it to an SSL object.

When QCA402x is configured as an SSL server, it needs to have a valid certificate that must be loaded from flash into the SSL object before the SSL connection object is created. Additionally, if the QCA402x SSL server needs to perform client authentication (mutual authentication), it also

needs to contain a valid CA list that must be loaded from flash into the SSL object before the SSL connection is created. This CA list is used to authenticate the client(s) connecting to the SSL server. The order in which certificates or CA lists are loaded is irrelevant.

When QCA402x is used as an SSL client, it needs to have a valid CA list that must be loaded from flash into the SSL object before the SSL connection is created. This CA List is used to authenticate the server(s) to which the client connects.

Additionally, if the client needs to authenticate itself with the server it connects to, the client must have a valid certificate that must be loaded from flash into the SSL object before the SSL connection is created. The order in which certificates or CA lists are loaded is irrelevant.

The code snippets show how to load certificate and CA list into the SSL object.

3.9.4.8.2.1 Load certificate into SSL object

```
qapi_Net_SSL_Obj_Hdl_t ssl_object = SSL_OBJECT_HANDLE;
qapi_Net_SSL_Cert_Type_t type = QAPI_NET_SSL_CERTIFICATE_E;
char * cert_name = CERTIFICATE_NAME;
qapi_Status_t status = qapi_Net_SSL_Cert_Load(object, type, cert_name);
```

3.9.4.8.2.2 Load CA list into SSL object

```
qapi_Net_SSL_Obj_Hdl_t ssl_object = SSL_OBJECT_HANDLE;
qapi_Net_SSL_Cert_Type_t type = QAPI_NET_SSL_CA_LIST_E;
char * ca_list_name = CA_LIST_NAME;
qapi_Status_t status = qapi_Net_SSL_Cert_Load(object, type, ca_list_name);
```

3.9.4.8.3 List available certificates and CA lists in flash

The `qapi_Net_SSL_Cert_List()` QAPI function is used to list certificates and CA lists that are stored in flash. A maximum of 10 certificates and 10 CA lists can be listed by this function. Each certificate or CA list name is limited to 64 characters.

The code snippets show how to list certificates and CA lists stored in flash.

3.9.4.8.3.1 List certificates stored in flash

```
qapi_Net_SSL_Cert_List_t * list_of_certificates = (qapi_Net_SSL_Cert_List_t
*) malloc(qapi_Net_SSL_Cert_List_t);
memset(list_of_certificates, 0, sizeof(qapi_Net_SSL_Cert_List_t));
qapi_Status_t status = qapi_Net_SSL_Cert_List(QAPI_NET_SSL_CERTIFICATE_E,
list_of_certificates);
int i;
for ( i = 0; i < QAPI_NET_SSL_MAX_NUM_CERTS; i++ ) {
   if ( strlen(list_of_certificates[i]) > 0 ) {
        printf("%s\n", list_of_certificates[i]);
   }
}
free(list_of_certificates);
```

3.9.4.8.3.2 List CA lists stored in flash

```
qapi_Net_SSL_Cert_List_t * list_of_certificates = (qapi_Net_SSL_Cert_List_t
*) malloc(qapi_Net_SSL_Cert_List_t);
memset(list_of_certificates, 0, sizeof(qapi_Net_SSL_Cert_List_t));
qapi_Status_t status = qapi_Net_SSL_Cert_List(QAPI_NET_SSL_CA_LIST_E,
list_of_certificates);
int i;
for ( i = 0; i < QAPI_NET_SSL_MAX_NUM_CERTS; i++ ) {
   if ( strlen(list_of_certificates[i]) > 0 ) {
        printf("%s\n", list_of_certificates[i]);
   }
}
free(list_of_certificates);
```

3.9.4.8.4 Calculate SHA256 checksum of certificate or CA list stored in flash

Because certificates are stored securely in TEE and are never given back to the host CPU, there must be a way to validate that the certificates are stored correctly. For this purpose, the `qapi_Net_SSL_Cert_Get_Hash`() function calculates the sha256 checksum of the certificate or CA list, returning 32 byte checksum that can be compared against the checksum calculated on a PC.

The code snippets show how to calculate SHA256 checksum of certificates and CA lists stored in flash.

3.9.4.8.4.1 Calculate SHA256 checksum of certificate stored in flash

```
char * cert_name = CERTIFICATE_NAME;
qapi_Net_SSL_Cert_Type_t type = QAPI_NET_SSL_CERTIFICATE_E;
uint8_t hash[32];
qapi_Status_t status = qapi_Net_SSL_Cert_Get_Hash(cert_name, type,
hash);
```

3.9.4.8.4.2 Calculate SHA256 checksum of CA List stored in flash

```
char * ca_list_name = CA_LIST_NAME;
qapi_Net_SSL_Cert_Type_t type = QAPI_NET_SSL_CA_LIST_E;
uint8_t hash[32];
qapi_Status_t status = qapi_Net_SSL_Cert_Get_Hash(ca_list_name, type,
hash);
```

3.9.4.8.5 Validating an external certificate

The qapi_Net_SSL_Cert_Validate QAPI function allows the caller to validate a peer certificate, which can be chained against a CA list in the local storage. The input certificate is in PEM format. QAPI accepts the peer common name to compare against the CN field of the certificate and verifies that the certificate has not expired.

This function is useful when there is a need to establish trust with an external peer without using TLS.

3.9.4.8.6 Certificate expiration test

The `qapi_Net_SSL_Cert_Get_Expiration` QAPI function allows the caller to get the expiration dates (not before and not after) of a certificate in the certificate storage. It allows the caller to determine whether a certificate is about to expire and take appropriate action.

3.9.4.8.7 Set up pre-shared key (PSK) table

The SSL PSK cipher suite requires the PSK table to be set up for the SSL object before the SSL connection object is created. The `qapi_Net_SSL_PSK_Table_Set`() QAPI function provides a mechanism to set up the PSK table. Each entry of the PSK table consists of identity and the corresponding pre-shared key.

The code snippet shows how to set PSK table for the SSL object.

```
qapi_Net_SSL_Obj_Hdl_t ssl_object_hdl = SSL_OBJECT_HANDLE;
uint16_t num_PSK_entries = 2;
qapi_Net_SSL_PSK_t * psk_entries = (qapi_Net_SSL_PSK_t *)
malloc(num_PSK_entries*sizeof(qapi_Net_SSL_PSK_t));
psk_entries[0].identity = { 0xca, 0xfe, 0xba, 0xba, 0x00 };
psk_entries[0].identity_Size = 5
psk_entries[0].psk = { 0xaa, 0xaa, 0xaa, 0xaa };
psk_entries[0].psk_Size = 4;
psk_entries[1].identity = { 0xca, 0xfe, 0xba, 0xba, 0x01 };
psk_entries[1].identity_Size = 5
psk_entries[1].psk = { 0xbb, 0xbb, 0xbb, 0xbb };
psk_entries[1].psk_Size = 4;
qapi_Status_t status = qapi_Net_SSL_PSK_Table_Set(ssl_object_hdl,
psk_entries, num_PSK_entries);
```

3.9.4.8.8 Clear the pre-shared key (PSK) table

When the SSL object is reused and the PSK table is no longer needed, it should be cleared using the `qapi_Net_SSL_PSK_Table_Clear`() QAPI functions. This function must be called only when there are no SSL connection objects associated with the SSL object.

The code snippet shows how to clear the PSK table for the SSL object.

```
qapi_Net_SSL_Obj_Hdl_t ssl_object_hdl = SSL_OBJECT_HANDLE;
qapi_Status_t status = qapi_Net_SSL_PSK_Table_Clear(ssl_object_hdl);
```

3.9.4.9 Create a new SSL object and connection

There are two objects for each SSL session:

- The SSL object containing the configuration related to SSL (supported ciphers, TLS or DTLS and so on)
- The SSL connection object containing the configuration related to the connection (like negotiated cipher, negotiated ALPN protocol).

An SSL object can have one of the following roles `QAPI_NET_SSL_SERVER_E` or

`QAPI_NET_SSL_CLIENT_E` based on the SSL configuration for a server or client.

To create an SSL object:

```
qapi_Net_SSL_Obj_Hdl_t qapi_Net_SSL_Obj_New(qapi_Net_SSL_Role_t role);
```

The QAPI returns a handle to the SSL object that must be used to reference the object until the SSL session is shut down and QAPI_NET_SSL_INVALID_HANDLE if the QAPI fails to create an SSL object. The handle is referred to as SSL context.

To create an SSL connection object:

```
qapi_Net_SSL_Con_Hdl_t qapi_Net_SSL_Con_New(qapi_Net_SSL_Obj_Hdl_t hdl,
qapi_Net_SSL_Protocol_t prot);
```

The handle, *hdl* is a handle to the SSL object and the protocol must be `QAPI_NET_SSL_TLS_E` or `QAPI_NET_SSL_DTLS_E` based on the transport (TCP or UDP).

The QAPI returns a handle to SSL connection object that must be used to reference a specific connection with a remote peer, until the connection is torn down and `QAPI_NET_SSL_INVALID_HANDLE` if the QAPI fails to create an object.

3.9.4.10 Configure SSL object and SSL connection

An application must create a configuration variable of type `qapi_Net_SSL_Config_t` and configure the different parameters.

An application can configure the SSL protocol to be any of the following `QAPI_NET_SSL_PROTOCOL_TLS_1_0`, `QAPI_NET_SSL_PROTOCOL_TLS_1_1`, `QAPI_NET_SSL_PROTOCOL_TLS_1_2`, `QAPI_NET_SSL_PROTOCOL_DTLS_1_0`, `QAPI_NET_SSL_PROTOCOL_DTLS_1_2` based on the transport (TCP or UDP).

Assuming cfg is a pointer to the configuration data, *cfg > verify* specifies the certificate verification policy.

- To verify the certificate's commonName against the peer's domain name, set *cfg > verify.domain* to 1.
- To verify certificate time validity, set *cfg > verify.time_Validity* to 1.
- To send an alert in case of error, set *cfg > verify.send_Alert* to 1.
- To enable a cipher for the SSL instance:

  ```
  qapi_Status_t qapi_Net_SSL_Cipher_Add(qapi_Net_SSL_Config_t * cfg,
  uint16_t cipher);
  ```

  The *cipher* can be `QAPI_NET_TLS_RSA_WITH_AES_256_GCM_SHA384`. For list of all ciphers, refer to the *QCA402x QAPI specification* (80-Y9381-7*)*.
- To set the maximum fragment length, set the value in *cfg > max_Frag_Len*.
- To disable negotiation of maximum fragment length, set *cfg > max_Frag_Len_Neg_Disable* to 1.
- For SNI, the application must specify the name of the server in *cfg > sni_Name* and the size or string length in *cfg > sni_Name_Size*.
- To configure ALPN use the QAPI:

  ```
  int qapi_Net_SSL_ALPN_Protocol_Add(qapi_Net_SSL_Obj_Hdl_t hdl, const
  char *protocol);
  ```

After configuring all the parameters, the application must use the QAPI to configure the SSL connection.

- To configure the SSL connection object:

```
qapi_Status_t qapi_Net_SSL_Configure(qapi_Net_SSL_Con_Hdl_t ssl,
qapi_Net_SSL_Config_t *cfg);
```

- Attach the socket descriptor to the SSL connection, using QAPI:

```
qapi_Status_t qapi_Net_SSL_Fd_Set(qapi_Net_SSL_Con_Hdl_t ssl, uint32_t
fd);
```

3.9.4.11 Connect and disconnect SSL sessions

SSL handshake is the process by which a client or server on QCA402x can establish an SSL session with a remote server or client.

3.9.4.11.1 TLS client

For a TLS client, after configuring the parameters, to connect to a remote server, a TCP session is established using qapi_connect (UDP does not need a connection). If the connection is successful, then an SSL connection object is created and configured using the QAPIs mentioned in 3.9.4.10.

- To initiate an SSL handshake:

```
qapi_Status_t qapi_Net_SSL_Connect(qapi_Net_SSL_Con_Hdl_t ssl);
```

  The QAPI returns `QAPI_SSL_OK_HS` if the handshake is successful. For information on other return values, refer to the *QCA402x QAPI specification* (80-Y9381-7*)*.

  After a successful handshake, the client can send data using `qapi_Net_SSL_Write`.

- To tear down a connection:

```
qapi_Status_t qapi_Net_SSL_Shutdown(qapi_Net_SSL_Con_Hdl_t ssl);
```

  The SSL connection object is freed in this QAPI. The application must invoke `qapi_socketclose` to close the socket.

- To free the SSL object:

```
qapi_Status_t qapi_Net_SSL_Obj_Free(qapi_Net_SSL_Obj_Hdl_t hdl);
```

3.9.4.11.2 TLS server

For a TLS server, open a TCP socket using `qapi_socket(`IPv4 or IPv6). Set the socket to listening mode using `qapi_listen`. Invoke `qapi_accept` to accept incoming connections. `qapi_accept` returns 1 if there are new incoming connections.

Create SSL object and connection object and configure these as described in sections 3.9.4.9 and 3.9.4.10. The connection object must be of type QAPI_NET_SSL_TLS_E.

Associate the TCP socket with the SSL connection using qapi_Net_SSL_Fd_Set.

- To complete the SSL handshake:

```
qapi_Status_t qapi_Net_SSL_Accept(qapi_Net_SSL_Con_Hdl_t ssl);
```

  The QAPI returns `QAPI_SSL_OK_HS` if the handshake is successful. For more information on other return values, refer to *QCA402x QAPI specification* (80-Y9381-7).

- To get the status of the connection (handshake), if the socket is in non-blocking mode:

```
qapi_Status_t qapi_Net_SSL_Con_Get_Status(qapi_Net_SSL_Con_Hdl_t ssl);
```

  After a successful handshake, the server can receive data using `qapi_Net_SSL_Read`.

- To tear down a connection:

```
qapi_Status_t qapi_Net_SSL_Shutdown(qapi_Net_SSL_Con_Hdl_t ssl);
```

- The SSL connection object is freed in this QAPI. The application must invoke `qapi_socketclose to close the socket.`
- To free the SSL object:
  `qapi_Status_t qapi_Net_SSL_Obj_Free(qapi_Net_SSL_Obj_Hdl_t hdl);`

3.9.4.11.3 DTLS client

1. Open a UDP socket using `qapi_socket` (IPv4 or IPv6).
2. Set the default address to which the datagrams are sent by calling qapi_connect with the address of the server. This is required for DTLS.
3. Create an SSL object and connection and configure these as described in sections 3.9.4.8, 3.9.4.9, and 3.9.4.10. The connection object must be of type QAPI_NET_SSL_DTLS_E.
4. Associate the UDP socket with the SSL connection using `qapi_Net_SSL_Fd_Set`.
5. Call `qapi_Net_SSL_Connect` to start the handshake with the server.

3.9.4.11.4 DTLS server

1. Open a UDP socket using `qapi_socket` (IPv4 or IPv6).
2. Create an SSL object and connection and configure these as described in sections 3.9.4.8, 3.9.4.9, and 3.9.4.10. The connection object must be of type QAPI_NET_SSL_DTLS_E.
3. Associate the UDP socket with the SSL connection using qapi_Net_SSL_Fd_Set.
4. Call `qapi_select` and until a client connects and sends data. `qapi_select` returns either if the timeout is reached or if a client completes the DTLS handshake and sends application data. If it is the latter, the decrypted application data can be read following the procedure in 3.9.4.12.

3.9.4.12 Send and receive data using TLS

Prior to sending or receiving data, the TLS handshake must be completed successfully, either when `qapi_Net_SSL_Connect` returns for blocking sockets, or a call to `qapi_Net_SSL_Con_Get_Status` returns QAPI_SSL_OK_HS for non-blocking sockets.

3.9.4.12.1 TLS sending data

To send data, the application must call `qapi_Net_SSL_Write`.

3.9.4.12.2 TLS receiving data

To receive data, the application needs to first call `qapi_select` to confirm that there is data pending in the socket queue, followed by a call to `qapi_Net_SSL_Read`.

3.9.4.12.3 DTLS sending data

Clients must call `qapi_Net_SSL_Write` after the handshake is complete (). Servers must call `qapi_Net_SSL_Write_To` which in addition takes the address of the client. Multiple clients may have connected.

To know that a client has connected and the address of that client, the client must first send data. The address of the call is obtained from the call to `qapi_Net_SSL_Read_From`.

The application must avoid IP layer fragmentation before calling `qapi_Net_SSL_Write` or `qapi_Net_SSL_Write_To`. Call `qapi_Net_SSL_DTLS_Client_Get_Data_MTU` to get the maximum payload size.

3.9.5 DHCPv4 client

The Dynamic Host Configuration Protocol (DHCP) v4 client service provides a collection of API functions that allow the application to manage automatic IPv4 configuration for a given network interface or acquire an IPv4 address from a DHCPv4 server. This configuration includes the interface IPv4 address, subnet mask, default gateway, and DNS configuration.

To initiate a DHCPv4 client transaction, the application needs to use the IP configuration `QAPI, qapi_Net_IPv4_Config,` and use the QAPI_NET_IPV4CFG_DHCP_IP_E option.

The application can register a callback using `qapi_Net_DHCPv4c_Register_Success_Callback`, which is called as the DHCPv4 client successfully acquires an IPv4 address from the server.

If the host no longer needs the IPv4 address obtained through DHCPv4 client, it may call `qapi_Net_DHCPv4c_Release` QAPI function to release its IPv4 address.

3.9.6 DHCPv4 server

The DHCP v4 server service provides a collection of API functions that allow the application to manage a local DHCPv4 Server configuration, which is used by clients attached to the device running the server.

DHCPv4 server is normally used in a device acting as a router (for example, Both QCMobileAP and STA interface are concurrently up and not bridged).

The application is required to configure the IPv4 address pool and lease time using the `qapi_Net_DHCPv4s_Set_Pool QAPI`, and the rest of the configuration is taken from the interface itself. It can optionally register to the success callback using `qapi_Net_DHCPv4s_Register_Success_Callback`, which is called when the local server has successfully assigned an IPv4 address to a remote host.

3.9.7 DHCPv6 client

DHCPv6 client is a mechanism to request an IPv6 address from the DHCPv6 server. If the DHCPv6 client needs to obtain an IPv6 address, it must first be enabled by calling the `qapi_Net_DHCPv6c_Enable` QAPI function. When this function is called, the DHCPv6 client module internally opens an IPv6 UDP socket on port 546.

If a router advertisement is received on the interface with the M bit set, the DHCPv6 client sends a solicit message to request an IPv6 address. Otherwise, the `qapi_Net_DHCPv6c_New_Lease` QAPI function needs to be called to explicitly send the solicit message to request an IPv6 address.

If the host does not need the IPv6 address obtained through DHCPv6 client, it may call `qapi_Net_DHCPv6c_Release_Lease` QAPI function to release its IPv6 address. Therefore, it may call the `qapi_Net_DHCPv6c_Disable` QAPI function to disable the DHCPv6 client, which internally closes the IPv6 UDP socket on port 546 that was previously opened with a call to `qapi_Net_DHCPv6c_Enable`.

The module is using callback to notify the caller when a new IPv6 address is obtained or released. It is recommended to register the `DHCPv6c_New_Lease_Complete_CB` (callback that is called when new IPv6 address is obtained) and the `DHCPv6c_Release_Lease_Complete_CB` (callback that is called when the IPv6 address is released) prior to calling the `qapi_Net_DHCPv6c_Enable` QAPI function.

3.9.7.1 Prefix delegation

The DHCPv6 client can also be used to obtain IPv6 prefix that is advertised on some other interface. This option is used when the device is used as a router and routes between external IPv6 network and local network.

To obtain an IPv6 prefix, the DHCPv6 must be enabled (using the `qapi_Net_DHCPv6c_Enable` QAPI function). The lease, the actual prefix, the `qapi_Net_DHCPv6c_New_Lease` function must be called with the first parameter being the interface name on which the DHCPv6 client is running and the second parameter is the interface name for which the prefix is appropriate.

To release the prefix, the `qapi_Net_DHCPv6c_Release_Lease` function must be called with the first parameter being the interface name on which the DHCPv6 client is running, and the second parameter being the interface name for which the prefix was previously obtained and now is required to be released.

3.9.8 DNS client

The domain name system (DNS) client service provides a collection of API functions that allow the application to configure DNS services in the system and translate domain names to their numerical IPv4 or IPv6 (or both) addresses. These APIs are needed for initiating communications with a remote server or service.

The DNS client service can be manually configured or automatically configured when the DHCP client is enabled.

To use the service, it first needs to be started by calling `qapi_Net_DNSc_Command(QAPI_NET_DNS_START_E)`. This call initializes the service and allocates resources. The service can be stopped using `qapi_Net_DNSc_Command(QAPI_NET_DNS_STOP_E)` or disabled using `qapi_Net_DNSc_Command(QAPI_NET_DNS_DISABLE_E)`.

After it is enabled, the DNS client reserves UDP port 53 to communicate with a DNS server and the application can use `qapi_Net_DNSc_Reshost, qapi_Net_DNSc_Get_Host_By_Name` or `qapi_Net_DNSc_Get_Host_By_Name2` QAPIs to resolve the address of a host. There are macros that allow portability of existing applications that use `gethostbyname` or `gethostbyname2`.

3.9.9 DNS server

The DNS server provides a name resolution service for the local network to resolve a host name to an IPv4/IPv6 address, when the device is used in router mode. If a host in the local network needs to resolve the address of another external host, the DNS server responds when the server has the answer or queries the next hop server (usually the Gateway) for the answer, and provides it back to the requesting host.

To use the service, the DNS server must be started by calling `qapi_Net_DNSs_Command(QAPI_NET_DNS_SERVER_START_E)`. This call initializes the service and allocates resources. The service can be stopped using `qapi_Net_DNSs_Command(QAPI_NET_DNS_SERVER_STOP_E)` or disabled using `qapi_Net_DNSs_Command(QAPI_NET_DNS_SERVER_DISABLE_E)`.

The local application can manually add or remove hosts in the local list using the `qapi_Net_DNSs_Add_Host` and `qapi_Net_DNSs_Del_Host` accordingly.

3.9.10 DNS-SD (service discovery)

DNS-based Service Discovery on QCA402x discovers services hosted by other devices on the local link. For a type of service and a domain, this service allows clients to discover a list of named instances of that appropriate service, using standard DNS queries.

Before starting DNS-SD, ensure that the interface has a valid IP address.

To discover services using DNS-SD, follow the sequence mentioned as follows:

1. To start DNS-SD:
   ```
   qapi_Status_t qapi_Net_DNSSD_Start(qapi_Net_DNSSD_Start_t *start);
   ```
2. To initialize DNS-SD:
   ```
   qapi_Status_t qapi_Net_DNSSD_Init(qapi_Net_DNSSD_Init_t *init);
   ```
   The `qapi_Net_DNSSD_Init` initializes DNS-SD with context information and allocates the receive buffer to handle discovery response. The *timeout* in `qapi_Net_DNSSD_Ctxt_t` has a maximum value of 5 seconds, even if the application specifies a large value.

   The *cb* (application callback) specified in the context is invoked with the result when a request is complete. The invocation of the callback happens in a timer context. So, the callback must be simple, where it copies the received data into an application buffer. The callback must complete as quickly as possible and should not perform any CPU-intensive operations as it might starve other timers and tasks in the system.

   The *max_Entries* is the total number of service response entries that the receive buffer can hold. The application programmer must be careful when providing this value, because, the system might run out of memory for an arbitrarily large value.

   It is recommended to set *max_Entries* to 5.
3. To start discovery:
   ```
   qapi_Status_t qapi_Net_DNSSD_Discover(const char *svcName);
   ```

After initialization is successful, an application can perform service discovery.

When a discover request is issued at the end of the timeout, a buffer of type `qapi_Net_DNSSD_Discover_t` is returned to the callback. This buffer is empty if no services were found. The buffer contains the service entries, if services corresponding to the type and domain were found, if the buffer is the pointer received by the application callback.

The *buffer->entries* parameter is a pointer to all the service instances that were received matching the service type and domain. *buffer->entries[i]* specifies the total number of service instances in the buffer and corresponds to each service instance. The *buffer->entries[i]->data_Count* specifies the number of data entries within that service instance.

For example, If the application received two instances of *_appletv._tcp.local*, hosted by two different devices on the local link, *instance1._appletv._tcp.local* and *instance2._appletv._tcp.local*, here is *buffer->entry*_Count is 2. Each of those service instances, *buffer->entries[i]* can have different data entries.

Based on the entry type specified by *buffer->entries[i]->data[j]->type,* the application must read the corresponding fields.

For example, If the type is `QAPI_NET_DNSSD_IPV4_ADDR`, then the callback must read the IPv4 address from parameter *buffer->entries[i]->data[j]->data.ipv4_Addr*.

There can be only one concurrent discovery request at any point in time. If the application issues a new discovery request before the previous one is complete (before timeout expires), a return value of `QAPI_ERR_BUSY` is returned to the application.

Other QAPIs:

- To stop DNS-SD:
  ```
  qapi_Status_t qapi_Net_DNSSD_Stop(qapi_Net_DNSSD_Ctxt_t *ctxt);
  ```
  This stoppage frees all the memory and resources allocated for the DNS-SD instance. No more discovery requests are possible.
- To get target server information:
  ```
  qapi_Status_t qapi_Net_DNSSD_Get_Target_Info(const char *svcName);
  ```
  The QAPI `qapi_Net_DNSSD_Get_Target_Info` retrieves information required to connect to a server hosting a specified service (obtained in service discovery) such as Server Name, port, and so on. This is usually a followup request to service discovery, because certain devices on the local link may not publish or send all the data related to a service with a single discovery request and might require subsequent requests.

3.9.11 HTTP client

The HTTP client service provides a collection of API functions that allow the application to establish connections to HTTP server and perform various HTTP methods. The HTTP client supports IPv4, IPv6, HTTP mode, and HTTPS mode (secure).

To use the HTTP client, it is required to start it, so resources are allocated using `qapi_Net_HTTPc_Start`. When the HTTP client services are not required, a call to `qapi_Net_HTTPc_Stop` releases all the resources.

3.9.11.1 Establish a connection

1. Before establishing a secure connection (using SSL), it is required to create an SSL object that is attached to the HTTP client session, using `qapi_Net_SSL_Obj_New`. Skip this step if secure connection is not required.
2. Create a session object using `qapi_Net_HTTPc_New_Sess` or `qapi_Net_HTTPc_New_Sess2`, which accepts the following arguments:
   - Timeout: Maximum time in ms for an HTTP request to wait for the response in this session.
   - SSL object: Created by `qapi_Net_SSL_Obj_New` and is required for secure HTTPS connections.

- Callback: An optional user-provided callback that is called to return the server's response.

  The arguments for the callback are:

  - Maximum HTTP body length in bytes
  - Maximum HTTP header length in bytes
  - Response buffer size in bytes (only for `qapi_Net_HTTPc_New_Sess2)`

  For secure connections, the application might need to configure SSL options before establishing the connection. The SSL configuration is passed using the `qapi_Net_SSL_Config_t` structure, followed by a call to `qapi_Net_HTTPc_Configure_SSL` to apply them to the current session.

3. Call `qapi_Net_HTTPc_Connect` and specify the session object and the destination port number.

3.9.11.2 Terminate a connection

- Use the `qapi_Net_HTTPc_Disconnect` call to terminate a connection.
- Use `qapi_Net_HTTPc_Free_sess` to terminate a connection and release all resources allocated for this connection. For secure connections, free the SSL object using `qapi_Net_SSL_Obj_Free.`

3.9.11.3 Set URL key-value pairs

Use the `qapi_Net_HTTPc_Set_Param` QAPI to add key-value pairs in URL encoding. The URL-encoded string is placed in the message body for POST request or after the question mark in the URL for GET request.

3.9.11.4 Set up the HTTP body

Use the `qapi_Net_HTTPc_Set_Body` QAPI to set up the HTTP body.

3.9.11.5 Modify the HTTP header

- Use the `qapi_Net_HTTPc_Add_Header_Field` QAPI to add HTTP header type-value fields.
- Use the `qapi_Net_HTTPc_Clear_Header` QAPI to clear the header.

3.9.11.6 Send an HTTP request

The HTTP client supports the following method requests (using `qapi_Net_HTTPc_Method_e`):

- GET
- PUT
- POST
- PATCH
- HEAD
- DELETE

- CONNECT

To request the method, use the `qapi_Net_HTTPc_Request` QAPI with the requested method and the URL.

3.9.11.7 HTTP tunneling

The HTTP CONNECT method can be used to create a tunnel. In this mechanism, the client asks an HTTP proxy server to forward the TCP connection to the required destination (called origin server). The proxy server proceeds to make the connection on behalf of the client. Once the connection is established, the proxy server continues to proxy the TCP stream to and from the client. Only the initial connection request is HTTP; post that, the proxy server proxies the established TCP connection. After using `qapi_Net_HTTPc_Connect` to connect to a proxy server, call `qapi_Net_HTTPc_Request` with `QAPI_NET_HTTP_CLIENT_CONNECT_E` to connect to the origin server. If the origin server is an HTTPS server, use `qapi_Net_HTTPc_Tunnel_To_HTTPS` to connect to the origin server. This QAPI starts an SSL handshake when the tunnel is established. After the tunnel is established, use `qapi_Net_HTTPc_Send_Data` to send any raw data to the origin server.

3.9.12 HTTP server

The HTTP server provides a collection of API functions that allow the application to enable and configure HTTP server. This can be configured to support IPv4, IPv6, or both, HTTP mode, HTTPS mode (secure), or both.

The HTTP server listens and accepts connection requests on the HTTP port. It reads the HTTP requests over that connection (socket), extracts key information into a data structure, and places the data structure on a queue for the Webserver.

The HTTP server can deal with clients that use HTTP 1.1 or the legacy HTTP 1.0 protocol. The HTTP 1.1 spec provides a standard for persistent connections. If the connection is persistent, then it can be reused for the subsequent requests related to the original request. If multiple requests are pipelined on a persistent connection, they are processed in the order in which they are received. With persistent connections, there are two ways to inform the client that the server has completed sending the requested data:

- If the data to be returned is a file or text message of the fixed length, the server uses the "*Content-length:* " header to inform the client the length of the response data.
- When the Web application (for example, Qualcomm Webserver) dynamically builds the return data, the length of the response cannot be known in advance. So, the server uses "*Transfer-Encoding: chunked\r\n*" header in the response to tell the client that data chunking is used.

The HTTP server supports Basic Authentication and Digest Authentication (MD5).

To enable HTTP server services, an HTTP server instance has to be created via the call to *qapi_Net_HTTPs_Init().* The function prototype of *qapi_Net_HTTPs_Init()* is declared in *qapi_httpsvr.h* as:

```
qapi_Status_t qapi_Net_HTTPs_Init(qapi_Net_HTTPs_Config_t *cfg);
```

Some configuration parameters required in *qapi_Net_HTTPs_Config_t* are:

- *mode* HTTP/HTTPS/Both
- *cert_File* The server certificate if mode is HTTPS or both

- *family* IPv4 or IPv6 or both

Other optional parameters must be set to zero.

If the server supports HTTPS, `qapi_Net_HTTPs_Set_SSL_Config()` can optionally be called to configure the SSL connection.

When the HTTP server initialization and configuration is done, `qapi_Net_HTTPs_Start()` must be called to start the service.

The HTTP server can be temporarily stopped by calling `qapi_Net_HTTPs_Stop()` which does not release resources used by the HTTP server. To restart the service, call `qapi_Net_HTTPs_Start()`.

The HTTP server can be shut down by calling `qapi_Net_HTTPs_Shutdown()` which stops the HTTP service, removes all configuration, releases all resources used, and deletes the server instance from the system.

3.9.12.1 Webserver

The Webserver is a web application that processes requests that have been placed on its queue by the HTTP server. It calls the internal functions and/or customers' CGI routines to perform the requested function or to deliver the requested pages. It uses HTTP server functions to format the HTTP response header and sends the response data or an error message to the client. The Qualcomm Webserver can handle GET, HEAD, PUT, and POST requests. With the Webserver, everything that can be done with a GET could be done with a POST. However, the reverse is not true. There are many tasks that can be done with a POST, but cannot be done with a GET. The GET is designed for simple requests that take only a few simple parameters. The POST is used to send the name/value pairs entered into a form. Only POST messages should be used to send requests with more than a simple set of parameters.

The client sends requests to:

- Obtain a file (normally done with GET)
- Request that one or more functions be performed on the server (GET or POST depending on whether form data is sent)
- Upload a file to the server (Not supported.)

The Webserver provides several QAPIs which the app can call to return HTTP response headers and HTTP response message body to the client.

For example, `qapi_Net_Webs_Send_HTTP_headers()` to send response headers.

`qapi_Net_Webs_Send_Data()` to send response message body.

For more information, see *qapi_webs.h*.

3.9.12.2 VFS

In addition to the local file system, the server can also use so-called Virtual File System (VFS) to store files or access CGI commands. VFS is a flat (non-hierarchical) file system, in which the files are stored in the target system memory (RAM or XIP) and are implemented as a linked list of *struct vfs_file* structures defined in *htmldata.h*. Each structure holds key information such as flags (for example, no/basic/digest authentication) and the file's size, and each has a pointer to a buffer that contains the associated file's contents. When the server locates a file, it goes to VFS first and if it cannot find the file goes to the local file system. VFS also stores a separate structure

for each CGI command. This allows the Webserver to obtain a pointer to the CGI routine as if it were a file.

3.9.12.3 VFS compiler

The VFS Compiler is a software program, which takes the files for web pages and "compiles" them into the C structures that become VFS files. The web page files can be any file normally put on a web server. HTML and GIF files are the most common, but the compiler can accept any binary file. The executable file for the VFS Compiler is *vfscomp.exe* (Windows) and *vfscomp* (Linux). Enter '*vfscomp*' to get the help message.

The programmer must provide a file as an input (for example, *input.txt*) to the compiler. This file contains a list of files that are to become part of the VFS, including the names of any GIF, JPEG, or Java bytecode files that we want in the VFS. It is a simple text file with one filename per line. Each file name may be followed by one or more options specifying how the compiler must handle each file.

Any kind of file can be included in *input.txt*. If the VFS Compiler does not understand the type (as indicated by the file extension), it encodes a binary image of the file.

The compiler takes the list of files in *input.txt* and produces, as output file, *htmldata.c*, which is to be linked into the final product image.

To invoke the compiler, enter the following in Windows or Linux shell:

```
vfscomp  -i  input.txt  -o  htmldata.c
```

3.9.12.4 Script file

In QCA402x server implementation, a Web file with the extension "*.iws*" or "*.iwx*" is called a "script" file. When a script file is requested, the Webserver parses the file looking for escape sequences that contain embedded commands or that lists one or more other files to include. An escape sequence in a script file always begins with the string

"*<#*" and ends with the string "*#>*". See an example in *index.iws*.

When the Webserver encounters the escape sequence, it performs the following:

1. Sends the file data prior to the escape sequence.
2. Parses out the include file or embedded command, including any parameters.
3. Executes the embedded command or read the include file.
4. Sends any data output as a result of the command execution or reading the include file.
5. Continues reading and output the file named in the request until it finds another escape sequence or the end of file.

If the file extension is "*.iws*", the Webserver sets the "*Content-type:* " header in the response to "*text/html*". If the file extension is "*.iwx*", it sets the "*Content-type:* " to "*text/xml*".

To include one file within another, the included filename must be within an escape sequence and the filename must be preceded by the word "*include*" and followed by a semicolon.

For example: *<# include* footer.html*; #>*. The file to be included must be known to the VFS or the local file system.

A single escape sequence might contain one or more commands and/or include files. Each command or include file must be followed by a semicolon. The semicolon separates multiple

commands, but it must always be used, even if there is only one command or one include file in the escape sequence. Within an escape sequence, white space characters are ignored (space, horizontal tab, new-line, vertical tab, and form-feed).

An embedded command can be:

- A built-in command ("*include*" or "*echo*")

  or

- The name of a user-defined CGI routine (a CGI command) known to VFS

  or

- A set of one or more commands, include files, or CGI commands within a single escape sequence.

The commands can be embedded within a script file simply by putting the command within an escape sequence at the point within the file where the output from the command execution is displayed. For example, `<# my_cgi_command; #>`.

An embedded command can include arguments.

Example:

```
<#
my_cgi_command  -x -f filename -n nvalue;
include myfile.htm;
#>
```

The built-in "*echo*" command is used to send text to the browser. The text to be sent is delineated by either single or double quotation marks (whichever is found first following the *echo* command.) The text within the quotation marks can contain any characters or escape sequences acceptable to the browser, except quotation marks. The text can contain semicolons. This permits the use of special HTML escape sequences such as " ", which is used to code a space. For example, *<# echo* "The current time is "; currtime; *echo* " GMT"; *#>*

The *echo* command forwards all characters between the beginning quotation mark and the ending quotation mark. In the previous example, the browser displays: "The current time is 10:14:11 GMT".

3.9.12.5 CGI

The CGI mechanism allows a GET or a POST to directly request the execution of a user-defined routine via the Webserver. The CGI routine can also be executed from an escape sequence in a *.iws* or *.iwx* file.

In the most common use of a CGI, the end-user on a browser first requests a HTML page from the server, which contains a form. The user fills in the form data and submits the form. The code that displays the form also specifies the name of the CGI routine that must be executed when the form is submitted.

Normally, a POST request is used, and the form data is appended to the filename as a string of url encoded text ("*Content-Type: application/x-www-form-urlencoded\r\n*"). It is also possible to call a CGI with a GET request. In this case, any parameter is attached to the request as a question mark separated list
(Example: *GET /cgidemo?name=Jessica&age=26&sex=female*). The file name or command (URI) indicated by the GET or POST is looked up in the VFS.

For CGI routines, the *struct vfs_file* for the file points to the CGI routine to be executed.

The HTTP server parses all form/parameter data from the GET or POST request and store them as name/value pairs in a form structure (`qapi_Net_Web_Form_t` in *qapi_webs.h*).

The Webserver subsequently calls the CGI routine and pass the `qapi_Net_Web_Form_t` to it. A programmer can use this CGI routine to perform the operations they desire with the passed data. The routine can change parameters on the server (for example, IP address), write any appropriate HTML text directly over the socket, or it can ask the Webserver to return a file. The function prototype of an CGI function is declared in *htmldata.h* as:

```
int (*cgi_func)(void *hp, void *form, char **filetext);
```

hp is an opaque handle from the Webserver

form is a pointer to a list of name/value pairs (`qapi_Net_Web_Form_t`)

filetext is currently not used
The return code from an CGI function must be one of the following values:

```
FP_ERR          /* Internal (code) error */
FP_DONE         /* CGI did everything, just clean up */
FP_BADREQ       /* Bad request from the browser */
```

If the return is not one of the preceding values, or if it is FP_ERR, the Webserver returns an HTTP *500 (Server error)* to the client. If the application wants to send a text message in response to the request, it must format the response, send it via `qapi_Net_Webs_Send_HTTP_headers(), qapi_Net_Webs_Send_Data() or qapi_Net_Webs_Send_String()`, and then return FP_DONE. This response indicates to the Webserver to clean up the connection. If the application returns FP_BADREQ, the Webserver sends an HTTP *400 (bad request)* response to the client with the text, "*Form Parse Error*".

The `qapi_Net_Webs_Get_Form_String(), qapi_Net_Webs_Get_Form_Int(), qapi_Net_Webs_Get_Form_Ip4addr(), qapi_Net_Webs_Get_Form_Ip6addr()` allow the CGI routine to obtain the value of a form entry by name.

Some clients may use POST to send data which is not URL-encoded to the web application. In this case, the Web application must register the content type of data by calling `qapi_Net_HTTPs_Register_Content_Type()`. The webserver passes the data of the registered type in the POST request to the Web application via a user-defined CGI function. This CGI function can in turn call `qapi_Net_Webs_Get_Message_Body()` to retrieve the data sent by the client. see sample CGI routines in *cgi_demo.c* and *cgi_showintf.c*.

3.9.12.6 Creating web application

The HTTP server needs to serve requests. At least one HTML page must be served. Whenever a connect to a Web server is made, without specifying a specific file (for example, by entering a URL such as http://192.168.2.100), the browser sends a GET request for a file, but the filename is only "/", the UNIX slash, for "root").

The server returns a default Web page when it receives a request of this type (The default web page can be changed by specifying *root_Index_Page[]* when the HTTP server is created). The default web page is called "*index.iws*" a sample of which is shown as follows:

```
<html>
   <head>
   <title>IOE Quartz</title>
```

```
</head>
<body>
<div>
<img src="iot_banner.png" alt=""
style="margin&#58;5px;width&#58;900px;height&#58;124px;" />
</div>
<!--
<form action="ABCD" method="post">
-or-
<form> /* "Get" method is used! */
-->
<form method="post">
  <br>
  Interface name: <input type="text" name="Intfname" maxlength="8" size="8"> <br>
  IPv4 addr: <input type="text" name="Ipv4addr" maxlength="16" size="16"> <br>
  Subnet mask: <input type="text" name="Subnetmask" maxlength="16" size="16">
<br>
  Default gateway: <input type="text" name="Gateway" maxlength="16" size="16">
  <input type="submit" value="Submit"> <br>
</form>

<br>
<# setintf; #>
<br>

<br>
<h2>
<# showintf; #>
</h2>

</body>
</html>
```

This Web page must be included along with other files and CGI commands in the VFS. Create a text file called "*input.txt*" which lists files and commands line by line. A sample *input.txt* is shown as follows:

```
   ######################################################
# -b                Basic authentication
# -d                Digest authentication
# -cgi <func>       <func> is an CGI routine
#
######################################################
# Request_URI       Options
#(files, commands)
#-----------------  -------------------------
index.iws           -d
iot_banner.png
setintf                -cgi     cgi_setintf
showintf               -cgi     cgi_showintf
cgidemo                -cgi     cgi_demo
cgidemobasic        -b -cgi     cgi_demo
cgidemomd5          -d -cgi     cgi_demo
```

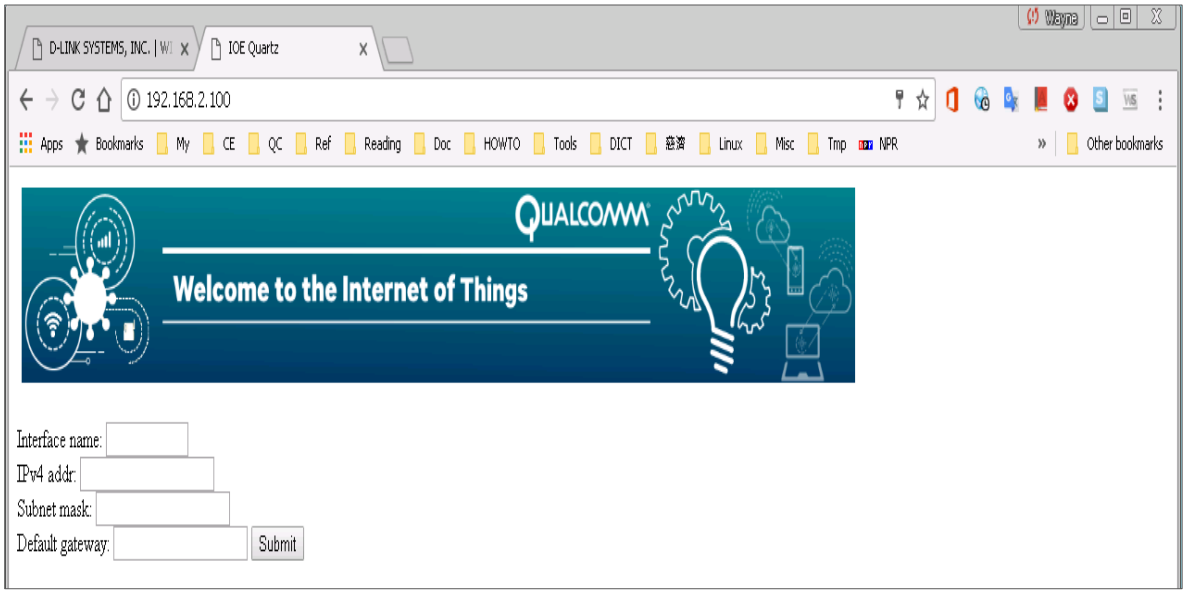
Run VFS compiler: `vfscomp  -i input.txt  -o  htmldata.c`

The compiler generates two files: `htmldata.c` and `htmldata.h`.

Any CGI function listed in input.txt has to be implemented. The implementation of the preceding three CGI functions in cgi_demo.c and cgi_showintf.c.

Compile `htmldata.c`, `cgi_demo.c` and `cgi_showuntf.c` and link them into the image.

Use a browser to display the default Web page:



3.9.13 mDNS server

Multicast-DNS (mDNS) server on QCA402x can be used to perform DNS like operations on local link in the absence of a conventional unicast DNS server. It uses the same existing DNS packet structure, name syntax, and resource record types. mDNS server supports both IPv4 and IPv6 and performs the following operations: registering a service, unregistering existing services, updating the TXT record of a registered service, and responding to DNS queries sent via IP multicast.

Before configuring mDNS server, ensure that the interface has a valid IP address.

To configure mDNS server, application programmers can use the QAPI `qapi_Net_mDNS_Command` with the following parameters:

- *command id:* mDNS command to be executed. For example, to startmDNS, use the command id `QAPI_NET_MDNS_START_E`.
- *input:* Input data varies based on the command ID. For example**,** if the command ID is `QAPI_NET_MDNS_START_E`, the input should be a pointer of `qapi_Net_mDNS_Start_t` type.
- *blocking:* This is a flag to indicate if mDNS server must function in the blocking mode or non-blocking mode. This flag is relevant only with `QAPI_NET_MDNS_START_E` and `QAPI_NET_MDNS_ADDSVC_E` commands. Even if mDNS server is in blocking mode, individual service registrations can be non-blocking.
- *app_CB:* Application callback that must be registered when starting mDNS server and cannot be modified.

Application programmers can also use individual QAPIs for each command like `qapi_Net_mDNS_Start`, `qapi_Net_mDNS_Stop`.

To configure mDNS server on QCA402x:

1. Start mDNS.

```
qapi_Status_t qapi_Net_mDNS_Start(qapi_Net_mDNS_Start_t *start,
qapi_Net_mDNS_CB_t app_CB, uint8_t blocking);
```

2. Set hostname.

   ```
   qapi_Status_t qapi_Net_mDNS_Set_Hostname(const char * host_Name);
   ```

   The hostname must preferably be of the form hostname.local. The QAPI returns QAPI_NET_STATUS_MDNSD_HOSTNAME_CONFLICT in case of hostname conflict. For all other errors, refer to *QCA402x QAPI specification* (80-Y9381-7).

3. Register a service.

   ```
   qapi_Status_t qapi_Net_mDNS_Register_Service(qapi_Net_mDNS_Svc_Info_t
   *svc_Info, uint8_t blocking);
   ```

   The service must be of the form <*instancename*>.<*servicetype*>.

   For example, *instance1._appletv._tcp.local*, here <*instancename*> is instance1 and <*servicetype*> is *_appletv._tcp.local*. The protocol can also be UDP if it is an UDP-based service. If *blocking* is set to 1, then the QAPI blocks until the operation is complete and returns the result. If *blocking* is set to 0, then the result is returned to the application callback asynchronously. A maximum of QAPI_NET_MDNS_MAX_TXT_RECORDS TXT records can be specified while registering a service. Each TXT record must be of the form "*key=value*" and a maximum length of 63 bytes.

- To stop the mDNS server:

  ```
  qapi_Status_t qapi_Net_mDNS_Stop(void);
  ```

  This removes all the registered services from mDNS server, frees all the resources, and stops the mDNS server.

- To unregister a specific service:

  ```
  qapi_Status_t qapi_Net_mDNS_Unregister_Service(const char *svc_Name);
  ```

- To update or add a new text record:

  ```
  qapi_Status_t qapi_Net_mDNS_Update_TXT(qapi_Net_mDNS_TXT_t *txt_Update);
  ```

  The text record must be of the form "key=value" **Example**: Version=1.0. If the key is an existing key, the value is updated to the new value. If the key is new, then a new text record is created.

3.9.14 MQTT client

The Message Queuing Telemetry Transport (MQTT) client service provides a collection of APIs that allow the application to implement client functionalities, such as CONNECT, SUBSCRIBE, UNSUBSCRIBE, PUBLISH and DISCONNECT.

`qapi_Net_MQTTc_Init()` must be called before any other MQTTc QAPI.

To provide services, a client instance must be created via the call to `qapi_Net_MQTTc_New`(). The number of client instances that can be created is limited by the available memory. If the client creation is successful, a handle is returned to the caller.

After a client instance is created, the application can call several QAPIs such as `qapi_Net_MQTTc_Set_Will(), qapi_Net_MQTTc_Set_Keep_Alive()` to configure the client:

```
Keep Alive
Will
```

```
Username and password
Wait time for CONNACK packet
Subscribe callback
Connect callback
```

If the client is to use SSL, `qapi_Net_MQTTc_Set_SSL_Config()` can be called to configure the SSL connection.

After the configuration is done, the app can call `qapi_Net_MQTTc_Connect()` to start a session with an MQTT broker. During the MQTT session, the app can subscribe some topics and/or publish some messages via `qapi_Net_MQTTc_Subscribe()` and `qapi_Net_MQTTc_Publish()`.

The status of the client is communicated to the app by two callbacks which the app has to register with the client. The app must call `qapi_Net_MQTTc_Register_Connect_Callback()` to register a connect callback to get all QAPI_NET_STATUS_MQTTC_xxxx (defined in `qapi_net_status.h`) status codes.

To get the subscription status (denied or granted) and the application messages published by other MQTT clients, the app must call `qapi_Net_MQTTc_Register_Subscribe_Callback()` to register a subscribe callback.

3.9.15 SNTP client

The Simple Network Time Protocol (SNTP) client service provides a collection of QAPI functions that allow the application to enable automatic acquisition of time from the network using SNTP.

After the acquisition of time is successful, the SNTP client updates the system time and the application can use the Time Services API to get the calendar time.

The SNTP client uses UDP port 123 to send and receive data and supports both IPv4 and IPv6.

To use the service, to the SNTP service must be started by calling `qapi_Net_SNTPc_Command(QAPI_NET_SNTP_START_E)`. This call initializes the service and allocates resources.

The service can be stopped using `qapi_Net_SNTPc_Command(QAPI_NET_SNTP_STOP_E)` or disabled using `qapi_Net_SNTPc_Command(QAPI_NET_SNTP_DISABLE_E)`.

The SNTP client service supports up to 2 servers, using `qapi_Net_SNTPc_Add_Server` or `qapi_Net_SNTPc_Del_Server`, where a default server that can be used is "pool.ntp.org".

The system time is maintained by the system during the runtime of the device, until a power cycle or a reset occurs, which requires acquiring the time again. For SSL connections, it is required that the system has the correct time to verify the expiration of server certificates.

3.9.16 WLAN bridging

WLAN bridging service provides a collection of QAPI functions that allow the application to set up and manage a 802.1D Bridge over two Wi-Fi interfaces; one is a QCMobileAP, and the other is a STA (or P2P equivalent).

The implementation ca transparent bridge uses forwarding database to send packets across the network links. The forwarding database is built as the bridge receives packets. If the destination

address packet is not found in the forwarding database, the packet is flooded to all ports of the bridge, except the port that received the packet.

Although a bridge is a Layer 2 function, the implementation must look at IP headers due to the physical limitation of WLAN networks and hops. The implementation uses the IP addresses to correlate between MAC addresses and hosts, and replaces the MAC addresses accordingly in order to be compliant with an upstream AP.

To enable the WLAN bridging functionality, the two WLAN interfaces have to be up and running, with no IP address configured to them (no traffic).
Use the `qapi_Net_Bridge_Enable` QAPI to enable the bridge.

It is possible to get the current forwarding database using `qapi_Net_Bridge_Show_MACs` and set the aging timeout of the entries using `qapi_Net_Bridge_Set_Aging_Timeout`.

3.9.17 Websocket client

The Websocket client is a collection of QAPIs to establish a connection with a Websocket server, and to send and receive messages. The Websocket client uses the HTTP client so it required to start the HTTP client using qapi_Net_HTTPc_Start before using the Websocket client. When finished with the Websocket client (and HTTP client), call qapi_Net_HTTPc_Stop.

3.9.17.1 Establish a connection

1. Before establishing a secure connection (using SSL), create an SSL object that is attached to the Websocket client context, using `qapi_Net_SSL_Obj_New`. If a secure connection is not needed, this step can be skipped.
2. Create a client context using `qapi_Net_Websocket_Client_New` with the following arguments:
   - Origin (optional): Client origin. NULL if origin is not specified.
   - Subprotocol list (optional): List of strings with supported subprotocols. NULL if subprotocol is not specified.
   - SSL object: Required for secure HTTPS connections.

     When SSL is used, call `qapi_Net_Websocket_Configure_SSL` to configure the SSL connection parameters.
   - Receive chunk size: Maximum amount of received message bytes buffered (see Section 3.9.17.3 Receive a message for details).
   - Handshake timeout: Connect timeout
   - Closing timeout: Closing timeout, if peer does not gracefully close within this timeout period, the Websocket is forcibly shutdown.
3. Register an event call back using `qapi_Net_Websocket_Register_Event_Callback`. The callback receives Websocket events − connection established, message received, pong received, or connection closed.
4. (Optional) Configure additional HTTP headers to include in the initial Websocket HTTP handshake. The application can add any HTTP header that are not standard headers already included by the HTTP or Websocket client. This can be done using `qapi_Net_Websocket_Client_Add_Handshake_HTTP_Header_Field`.

5. Call `qapi_Net_Websocket_Client_Connect` to establish the connection to the server. The server hostname or IP address, server port, and the resource path are specified as arguments. This is a non-blocking call. When the connection is established (this occurs when the server responds with a valid handshake response), the registered event callback receives an event of `QAPI_NET_WEBSOCKET_EVENT_CONNECT_E` type. If a list of supported subprotocols has been configured, the event info (`qapi_Net_Websocket_Event_Info_t`) provided to the callback contains the negotiated subprotocol.

   If the server responds with an invalid response or the connection times out, the event callback receives an event of `QAPI_NET_WEBSOCKET_EVENT_CLOSE_E` type.

3.9.17.2 Send a message

To send a message, call `qapi_Net_Websocket_Send`. The data type (TEXT or BINARY), data, data length, and end of message flag are passed as arguments. When the message is sent in a single call, the end of message flag is set to TRUE. However, for large messages when there is not enough memory to send the entire message at once, the message can be sent in fragments. This can be done by doing multiple calls to `qapi_Net_Websocket_Send`. Each call sends a fragment of the message. The final call must have the end of message flag set to TRUE. Prior calls must have the flag set to FALSE.

For example, two calls can be used to send a single message as two fragments − "hello" and "world", but the receiving application sees only the final message "helloworld".

```
qapi_Net_Websocket_Send(websocket_hdl,
QAPI_NET_WEBSOCKET_DATA_TYPE_TEXT_E,
        "hello", // data
        5, // data length
             FALSE); // end of message flag
qapi_Net_Websocket_Send(websocket_hdl,
QAPI_NET_WEBSOCKET_DATA_TYPE_TEXT_E,
        "world", // data
        5, // data length
             TRUE); // end of message flag
```

The call to send returns the number of bytes sent. When there is a scarcity of network resources, it is possible that only a part of the message is sent. In this case, the bytes returned maybe less than the requested bytes to send. If this occurs, the application must call send again (after a delay) on the remaining bytes of the message. For example, if send is called for the message "helloworld" and returns 3, it indicates that only the first three bytes "hel" were sent. The application must call send on "loworld", and send the rest of the message. If send fails to send the entire message at once, the application should not send another message until sending the current message is complete.

3.9.17.3 Receive a message

The messages are received through the registered event callback. When a message is received, the callback gets an event of type `QAPI_NET_WEBSOCKET_EVENT_MESSAGE_E`, and associated event info of type `qapi_Net_Websocket_Event_Info_t` with the data type (TEXT or BINARY), data, and length of the message. Finally, there is an end of message flag that is set to either TRUE or FALSE. The purpose of this flag is explained here.

Since there may not be enough memory to receive the entire message at once, it is left up to the application to configure the maximum number of bytes to buffer. This is controlled by the receive chunk size parameter while creating the client context (this is not related to a "chunk" in HTTP). When this maximum is reached but there are more bytes in the message to be received, the application is called with the data buffered so far with the end of message flag set to FALSE. If there are no more bytes to be received in the message, the end of message flag is TRUE. For example, if the receive chunk size is 1024 and the server sends a 2560-byte binary message, the event callback is called three times:

1. (data_Type = BINARY, data_Length = 1024, data = [Bytes 1…1024], end_Of_Message = FALSE)
2. (data_Type = BINARY, data_Length = 1024, data = [Bytes 1025…2048], end_Of_Message = FALSE)
3. (data_Type = BINARY, data_Length = 512, data = [Bytes 2048…2560], end_Of_Message = TRUE)

The data type for TEXT data must be UTF-8; this not enforced by the Websocket implementation and must be validated by the application if necessary.

3.9.17.4 Ping and Pong

Either endpoint can ping (at the Websocket layer) the other endpoint and receive a pong in response. A pong can also be sent as an unsolicited heartbeat if the application chooses to use it in that way. To send a ping, call `qapi_Net_Websocket_Ping`. In response, the registered event callback gets an event of type `QAPI_NET_WEBSOCKET_EVENT_PONG_E`. To send an unsolicited heartbeat, call `qapi_Net_Websocket_Pong`.

3.9.17.5 Connection close

A graceful close of Websocket requires the closing side to send a close frame and wait for the peer to respond with a close frame at which point the connection can be closed. If the server closes the connection, the registered event callback will get an `QAPI_NET_WEBSOCKET_EVENT_CLOSE_E` event.

To initiate a close from the client, call `qapi_Net_Websocket_Close`. Once the server replies with a close frame, the event callback gets a `QAPI_NET_WEBSOCKET_EVENT_CLOSE_E` event.

If the server does not respond with a close frame within the configured close timeout, the connection is forcibly shutdown. The event callback still gets a close event in this case.

For both the client or server initiated close, event info for a close event contains a close status code. This is set by the server to indicate why the connection was closed.

After closing a connection, the Websocket client context can be used again for a new connection.

If the client context is no longer needed, it can be freed using `qapi_Net_Websocket_Client_Free`.

3.9.17.6 Debugging

The `qapi_Net_Websocket_Get_Opt` can be used to get information about the connection that is useful for debugging purposes. The information returned is based on the option type passed to the function. These include:

- STATE: Current state of the connection (example: OPEN, CLOSED)
- ERRNO: Last connection error while sending or receiving a message or handshake error.
- SOCKET ERRNO: If errno is `QAPI_NET_WEBSOCKET_STATUS_SOCKET_ERROR`, this gets the underlying socket's errno.
- SSL ERRNO: if errno is `QAPI_NET_WEBSOCKET_STATUS_SSL_ERROR`, this gets the last SSL error.
- Rx BYTES: Total number of bytes received after the connection is established
- Tx BYTES: Total number of bytes sent after the connection is established
- Rx PINGS: Total number of pings received
- Tx PINGS: Total number of pings sent
- Rx PONGS: Total number of pongs received
- Tx PONGS: Total number of pongs sent

3.9.18 CoAP client

The constrained application protocol (CoAP) client service provides a collection of API functions that allows the application to establish connections to the CoAP server and perform various CoAP methods. The CoAP client supports IPv4, IPv6, TCP, UDP, CoAP mode, and CoAPS mode (secure).

To use the CoAP client, run `qapi_Net_Coap_Client_Start` so that the resources are allocated.

When the CoAP client services are not required, call `qapi_Net_Coap_Client_Stop` to release all the resources.

3.9.18.1 Establish a connection

1. Before establishing a secure connection using SSL, create an SSL object that is attached to the CoAP client session, using `qapi_Net_SSL_Obj_New`. This step is optional if a secure connection is not required.
2. Create a session object using `qapi_Net_Coap_Client_New_Context`, which accepts the following arguments:
   - Protocol: Indicate to connect server by using UDP or TCP.
   - SSL object: Created by `qapi_Net_SSL_Obj_New` and is required for secure HTTPS connections.
   - A callback: An optional user provided callback that is called to return the server's response.
   - An argument for the callback.

NOTE: For secure connections, the application configures SSL options before establishing the connection. The SSL configuration is passed using the `qapi_Net_SSL_Config_t` structure, followed by a call to `qapi_Net_Coap_Client_SSL_Config` to apply them to the current session.

3. Call `qapi_Net_Coap_Client_Connect` and specify the session object, the server address, and the destination port number.

3.9.18.2 Terminate a connection

Use `qapi_Net_Coap_Client_Free_Context` call to terminate a connection.

Use `qapi_Net_Coap_Client_Stop` to terminate all clients and release all resources allocated for this connection.

Use `qapi_Net_Coap_Client_Start` to start the CoAP client again.

3.9.18.3 Send a CoAP message

Use the `qapi_Net_Coap_Client_Send_Msg` QAPI to send a request to CoAP server with these parameters:

- coap context: Created when establishing a connection.
- Uri: URI in CoAP server
- Payload: Payload in the request
- Payload_length: Payload length
- Method: GET/PUT/POST/DELTE
- Message type: Confirmable or non-confirmable

3.9.18.4 Set configuration parameter

Use the `qapi_Net_Coap_Client_Add_Parameter` QAPI to configure these parameters:

- qapi_Net_Coap_Para_Flag: Indicates the type of the add parameter as follows:
  - QAPI_COAP_PARAMETER_FLAG_OPTION
  - QAPI_COAP_PARAMETER_FLAG_TOKEN
  - QAPI_COAP_PARAMETER_FLAG_BLOCK
  - QAPI_COAP_PARAMETER_FLAG_TIMEOUT
- Type: Used when flag is QAPI_COAP_PARAMETER_FLAG_OPTION and QAPI_COAP_PARAMETER_FLAG_TIMEOUT.
  - When the flag is QAPI_COAP_PARAMETER_FLAG_OPTION, this type indicates if the option is URI path or URI query.
  - When the flag is QAPI_COAP_PARAMETER_FLAG_TIMEOUT, this type indicates the type of timeout. It can be COAP_PARAMETER_TYPE_TIMEOUT_SEND and COAP_PARAMETER_TYPE_TIMEOUT_OBSVER.
- Data: Value of the add parameter.
- Length: Length of the data.

3.9.19 CoAP server

The CoAP server provides a collection of API functions that allow the application to enable and configure the CoAP server. This can be configured to support:

- IPv4, IPv6, or both
- UDP, TCP or both
- TLS, DTLS, or both

Call `qapi_Net_Coap_Server_New_Context` to create a new server context. The parameters are:

- `qapi_Net_Coap_Server_Cfg_t`: To enter interface name, port name, multicast enable/disable, certificate filename, IPv4/IPv6, and UDP/TCP.
- SSL object: Created by `qapi_Net_SSL_Obj_New` and is required for secure HTTPS connections.

Call `qapi_Net_Coap_Server_Start` to start the server, and `qapi_Net_Coap_Server_Stop` to stop the server.

For secure connections, the application configures SSL options before establishing the connection. The SSL configuration is passed using the `qapi_Net_SSL_Config_t` structure, followed by a call to `qapi_Net_Coap_Server_SSL_Config` to apply them to the current session.

3.9.19.1 Server resource setup

1. Call `qapi_Net_Coap_Server_Resource_Init` to initial the resource. The parameters of this function are the URI, and the length of URI.

   The flag indicates if this resource must be observed. If the resource must be observed, set QAPI_COAP_RESOURCE_FLAGS_NOTIFY_CON; else, set the flag to 0. The return value of this function is a pointer of qapi_Net_Coap_Resource_t.

2. Call `qapi_Net_Coap_Server_Resource_Register_Handler` to register the handler of this resource. The parameters are:

   - resource: Return value of `qapi_Net_Coap_Server_Resource_Init`
   - method: GET/POST/PUT/DELETE
   - handler: Handler register for this resource.

     The `qapi_Net_Coap_Method_Handler_t` must be defined as follows. The implementation must refer to the resource handler in the coap_demo.c.

```
typedef void (*qapi_Net_Coap_Method_Handler_t)
  (qapi_Net_Coap_Context_t*,
    qapi_Net_Coap_Resource_t*,
 qapi_Net_Coap_Address_t *,
 qapi_Net_Coap_Pdu_t *,
 qapi_Net_Coap_Str_t * /* token */,
      qapi_Net_Coap_Pdu_t * /* response */);
```

3. Call `qapi_Net_Coap_Server_Add_Attr` to add an attribute to a resource. The parameters are:

   - resource: Return value of `qapi_Net_Coap_Server_Resource_Init`

- name: Attribute name
- name length
- attribute value
- attribute value length

4. Call `qapi_Net_Coap_Server_Add_Resource` to add a resource to the server context. The parameters are:
   - context: Return value of `qapi_Net_Coap_Server_New_Context`
   - resource: Return value of `qapi_Net_Coap_Server_Resource_Init`

The following APIs are used in the resource handler:

- `qapi_Net_Coap_Server_Add_Option`: Add option in PDU.
- `qapi_Net_Coap_Server_Add_Data`: Add data in PDU.
- `qapi_Net_Coap_Server_Find_Observer`: Find an observer based on peer address and token ID.
- `qapi_Net_Coap_Server_Check_Option`: Check if it has a certain option.
- `qapi_Net_Coap_Server_Get_Data`: Get PDU data.
- `qapi_Net_Coap_Server_Add_Block`: Add block information in PDU.
- `qapi_Net_Coap_Server_Register_Async`: Register the async resource.

The following APIs set the status of resource:

- `qapi_Net_Coap_Server_Resource_Set_Observable`: Set the observable resource.
- `qapi_Net_Coap_Server_Resource_Set_Dirty`: Set the resource to dirty.

3.10 Thread

The integrated Thread library operates as a network interface for the integrated network stack. Features include:

- Support for all device roles (SED, FED, Router, Leader, Border Router, Commissioner, and so on).
- Support for on-mesh and off-mesh commissioning.
- Integrated into QCA402x network stack.

3.10.1 Network address management

The Thread APIs must be used, instead of the network services APIs during the addition or removal of unicast or multicast addresses to the Thread network interface.

3.10.2 Low-power mode

QCA402x can enter SOM (section 3.3) when the thread stack is initialized. For the system to enter SOM, the thread must either be operating as a sleepy end-device or idle (not operating on a network).

MOM mode must not be used when the Thread stack is operating on a network.

3.11 ZigBee

The ZigBee library provides the functionality required to support ZigBee PRO and ZigBee 3.0 features. The features include:

- ZigBee PRO R21
- Green Power Proxy
- Base Device Behavior and ZigBee 3.0
- Support for end device, router, and coordinator device roles
- ZigBee Cluster Library R6:
  - Alarm
  - Basic
  - Color Control
  - Device Temperature Configuration
  - Groups
  - Identify
  - Level Control
  - On/Off
  - OTA
  - Power Configuration
  - Scenes
  - Time
  - Qualcomm® Touchlink™

3.11.1 ZigBee DevCfg

The following ZigBee configurations can be modified using DevCfg:

Name	ID	Description
Flags	0x00001000	Configuration flags for ZigBee. Bit 0: Enable Green Power Proxy If this flag is set, the GPP is initialized with the ZigBee stack. This is required for Certifcation of router and coordinator devices. However, these must be disabled for end devices.
Poll Period	0x00001001	Period in milliseconds the parent is polled when configured as a sleepy device.
Basic Application Version	0x00001101	Value of the Basic cluster's ApplicationVersion attribute.
Basic Stack Version	0x00001102	Value of the Basic cluster's StackVersion attribute.
Basic Hardware Version	0x00001103	Value of the Basic cluster's HWVersion attribute.
Basic Manufacturer Name	0x00001104	Value of the Basic cluster's ManufacturerName attribute.
Basic Model Identifier	0x00001105	Value of the Basic cluster's ModelIdentifier attribute.
Basic Date Code	0x00001106	Value of the Basic cluster's DateCode attribute.
Basic SW Build ID	0x00001107	Value of the Basic cluster's SWBuildID attribute.
NWK Address Map Table Size	0x00001200	Size of the NWK address map table.
NWK BTT Table Size	0x00001201	Size of the NWK Broadcast Transaction Table.

Name	ID	Description
NWK Max Packets	0x00001202	Maximum number of outstanding NWK packets allowed.
NWK Neighbor Table Size	0x00001203	Size of the NWK neighbor table.
NWK Route Table Size	0x00001204	Size of the NWK route table.
NWK RREC Table Bits	0x00001205	Number of bits in the Route Record hash table (the actual size of the table is 2^n).
NWK RREC Table Overflow	0x00001206	Number of overflow entries for the Route Record hash table.
NWK RREQ Table Size	0x00001207	Size of the NWK Route Request table.
NWK LQI Cost Map	0x00001208	A 6-byte array that maps LQI to route cost. The array entries[0–5] represent the minimum LQI values that correspond to the route cost [1–6]. The minimum LQI for a route cost of 7 is always 0.
APS Binding Table Size	0x00001300	Size of the APS binding table.
APS Device Key Pair Count	0x00001301	Number of device key pairs that can be retained.
APS Group Table Size	0x00001302	Size of the APS group table.
APS Max Packet Size	0x00001303	Maximum APS packet size.

3.11.2 Green power proxy

The ZigBee stack has integrated support for the Green Power Proxy as required by the R21 specification. If it is enabled using DevCfg, the proxy is automatically initialized with the ZigBee stack and the typical application does not need to interact with Green Power any more.

3.11.3 Low-power modes

QCA402x can enter SOM (Section 3.3) when the ZigBee stack is initialized. For the system to enter sensor operating mode (SOM), ZigBee must be operating as a sleepy end device or idle (not operating on a network). Additionaly, SOM mode is not supported if the Green Power Proxy is enabled via DevCfg.

Before entering SOM, a SOM transition region must be created. The size required for this region is largely dependent on the ZigBee stack configuration and the clusters that are initialized. It is recommended that the ZigBee configuration options are reduced to the minimum acceptable levels if the application intends to use SOM.

NOTE: Minimum operating mode (MOM) is not supported when the ZigBee stack is initialized.

3.11.4 Legacy support

While operating as a trust center, the BDB v1.0 specification (section 10.3.2) requires a joining device undergo the link key exchange procedure for ZB 3.0 if the bdbTrustCenterRequireKeyExchange BIB is set to true (its default value). If a device that does not support the link key exchange procedure attempts to join the network, it is directed to leave before the join process completes which can cause compatibility issues with devices that do not implement BDB. To allow legacy devices to join the network, the bdbTrustCenterRequireKeyExchange BIB needs to be set to false after the stack has been initialized.

3.12 Cryptographic operations

The crypto library provides a collection of API functions that allow the application to perform various cryptographic operations such as:

- Digests (SHA1, SHA256, SHA384, SHA512, MD5)
- Ciphers (AES-CBC, AES-CTR, RSA V1.5, RSA no padding)
- Key exchange (DH, ECDH, SRP, CURVE25519)
- Signature (ECDSA, RSA, ED25519)
- Authenticated encryption (AES-CCM, AES-GCM, ChaCha20Poly1305)
- Message authentication (HMAC)

The supported algorithms are mentioned inside the parentheses. The crypto QAPIs are designed to be compatible with those defined by Global Platform, a cross-industry, non-profit association that publishes specifications for the deployment of secure applications.

"Objects" are the keys used in the crypto operations and "operations" are the cryptographic functions performed on the keys (sign, key generation and so on).

3.12.1 Secure storage

The secure storage module provides a service that encrypts and authenticates files in the flash file system. It provides QAPIs to carry out basic operations on encrypted files. The QAPIs supported by this module allow clients to carry out the following operations:

- Open an existing secure storage file or create a new file using `qapi_Securefs_open`
- Read and write to a secure storage file within file system using `qapi_Securefs_write` and `qapi_Securefs_read` accordingly.
- Seek to a specific plain text offset using `qapi_Securefs_Lseek`
- Get the current plain text offset of a file using `qapi_Securefs_Tell`
- Close a secure storage file using `qapi_Securefs_close`

The open command allows the caller to specify standard access flags and a unique password that is used to encrypt and decrypt the file. If no password is provided, a default password is used. Thus, no secure file is stored in plain-text. When using the `QAPI_FS_O_SYNC` flag, all write operations to the file are synchronized. The entire file is encrypted and signed for each write operation.

The Secure storage QAPIs can take time in the order of seconds to complete the operation, depending on the access speeds of the underlying flash media. The calling tasks/clients must be prepared to be blocked for this duration. It is mandatory to avoid calling secure storage QAPIs in time critical sections of the code.

3.12.2 Transient object operations

Transient objects are cryptographic keys that exist in memory while the device is powered on. QAPIs exist for creating and deleting objects. Transient and persistent objects are sent as input to the crypto operations APIs.

Each object has an object type. The object type begins with the prefix `QAPI_CRYPTO_OBJ_TYPE_″`.

For example, QAPI_CRYPTO_OBJ_TYPE_RSA_KEYPAIR_E represents an RSA key pair.

Objects contain attributes. The attributes begin with the prefix "QAPI_CRYPTO_ATTR_".

For example, an RSA key pair object contains the attribute QAPI_CRYPTO_ATTR_RSA_MODULUS_E which represents the RSA modulus value.

There are four ways to create a transient object:

- Through importing a transient object from a PEM file.
- Through populating the attributes of the object.
- Through key generation.
- Through key derivation.

3.12.2.1 Create an object from a PEM file

PEM is a standard file format for RSA and ECC key pairs or public keys. Create a transient object from a PEM file using qapi_Crypto Transient_Obj_Import_From_Pem.

3.12.2.2 Create an object by populating its attributes

Allocate a new transient object using qapi_Crypto_Transient_Obj_Alloc. This requires specifying the key size of the object in bits.

- For HMAC, the key size is variable. The lower and upper bounds are defined in macros with the suffix "_MIN_KEY_BITS" and "_MAX_KEY_BITS".
- For AES, the key can be 128 or 256 bits. It is defined in the macros QAPI_CRYPTO_AES128_KEY_BITS and QAPI_CRYPTO_AES256_KEY_BITS.
- For RSA, the key size is the modulus size. The maximum modulus size supported is 4096.
- For ECC based algorithm, the key size depends on the curve that is used. For example, ECDSA. For ECC curves, the types are defined by macros of the form QAPI_CRYPTO_ECC_CURVE_NIST_P<CURVE> where <CURVE> is the ECC curve. The supported ECC curves are secp192/224/256/384.
- For key pairs, the sizes are defined by macros of the form QAPI_CRYPTO_ECC_<CURVE>_KEYPAIR_BITS where <CURVE> is the ECC curve. For public keys, the sizes are defined by macros of the form QAPI_CRYPTO_ECC_<CURVE>_PUBLIC_KEY_BITS.

Constants are also defined for ED25519, CURVE25519, and CHACHA20_POLY1305.

1. Create an array of qapi_Crypto_Attrib_t structures that contain the attributes for the object. Each qapi_Crypto_Attrib_t structure has an attribute id and value. The value can be a buffer or a numeric value. The attribute IDs are defined by macros prefixed by "QAPI_CRYPTO_ATTR_".
2. Populate the object with the attributes using qapi_Crypto_Transient_Obj_Populate.

3.12.2.3 Create an object using key generation

1. Allocate a new transient object using qapi_Crypto_Transient_Obj_Alloc.

2. Create an array of `qapi_Crypto_Attrib_t` structures that contain the attributes for the object.
3. Generate the keys for the object using `qapi_Crypto_Transient_Obj_Key_Gen`.

3.12.2.4 Creating an object using key derivation

A key derivation operation can be used to create an object of type `QAPI_CRYPTO_OBJ_TYPE_GENERIC_SECRET_E`, which represents a generic secret. For more information on key derivation, see Section 3.12.5.6.

3.12.3 Delete transient objects

Use `qapi_Crypto_Transient_Obj_Free` to free the transient object and free any resources that it uses.

3.12.4 Persistent object operations

Persistent objects such as transient objects are cryptographic keys. The transient objects are securely stored on flash (with encryption and integrity protection). When the object is created, it is associated with an object id. A handle to the persistent object can be reopened at any time using the object id. From an application developer's perspective, after the handle to persistent object is opened, they can be used in the same way as transient objects are inputs to the cryptographic operations QAPIs. One caveat is that persistent objects do not support some of the algorithms that were extensions to the original global platform specification. Supported algorithms are ECDSA, RSA, AES, and the HMAC and hash algorithms.

A persistent object can be created from an existing transient object or an existing persistent object using **`qapi_Crypto_Persistent_Obj_Create.`**

- `storage_Id` must be QAPI_CRYPTO_PERSISTENT_OBJ_DATA_TEE_STORAGE_PRIVATE
- `object_Id` is a binary identifier for the object of `QAPI_CRYPTO_PERSISTENT_OBJECT_ID_MAX_LEN` (64) bytes
- `flags` can either be 0 or `QAPI_CRYPTO_DATA_EXCLUSIVE`. If it is the latter, and an object with object_Id already exists, an error is returned. If the flag is not set, the existing object is over written.
- `Attributes:` Attribute is either a handle to a transient object or a persistent object. The attributes for the new object is populated from this object.
- `initial_Data` and `initial_Data_Len` are reserved for future use and must be set to NULL and zero respectively.

A handle to a persistent object that has already been created can be opened using `qapi_Status_t` **`qapi_Crypto_Persistent_Obj_Open.`** The flags can either be 0 or `QAPI_CRYPTO_DATA_ACCESS_WRITE_META`. The latter is needed if the handle is used to delete or rename an object.

Other supported operations are:

- Close a handle to a persistent object using `qapi_Crypto_Persistent_Obj_Close`

- Close a handle to a persistent object *and* delete it from flash using `qapi_Crypto_Persistent_Obj_Close_and_Delete`
- Rename an object to another object id using `qapi_Crypto_Persistent_Obj_Rename`
- Read the public attributes of RSA or ECDSA keys using qapi_Crypto_Obj_Buf_Attrib_Get or qapi_Crypto_Obj_Val_Attrib_Get.

The persistent objects that exist on the device can be enumerated.

- Allocate an enumerator using qapi_Crypto_Persistent_Obj_Enumerator_Alloc and start enumeration using qapi_Crypto_Persistent_Obj_Enumerator_Start.
- Get the next object information using qapi_Crypto_Persistent_Obj_Enumerator_Get_Next. Repeat until QAPI_ERR_NO_ENTRY is returned at which point, there are no more objects to enumerate.
- Free the enumerator using qapi_Crypto_Persistent_Obj_Enumerator_Free.

NOTE: The changes on the file system such as a persistent object being deleted, while an enumerator is open, it causes undefined behavior.

3.12.4.1 Importing persistent objects from certificate store

The certificate manager APIs (section 3.9.4.8 SSL certificate manager) provide a way to store certificates with their associated public and private keys. Typically, the certificates and keys are used for SSL. To use the crypto QAPIs with keys stored in the certificate store, the application must import the key pair associated with a certificate into a persistent object using the `qapi_Crypto_Persistent_Obj_Import_From_Cert_`Store QAPI. The QAPI takes the name of the certificate and the ID of the persistent object which contains the copy of key pair associated with the certificate.

3.12.5 Crypto operations

3.12.5.1 Basic operations

- Allocate a crypto operation using `qapi_Crypto_Op_Alloc`.
- Set the key used by the crypto operation using `qapi_Crypto_Op_Key_Set`. The key may be a transient object or a persistent object.
- After using the object, free it using `qapi_Crypto_Op_Free`.

3.12.5.2 Digest operations

- Allocate the digest operation.
- Update the digest using `qapi_Crypto_Op_Mac_Update` (Optional).
- Compute the final digest using `qapi_Crypto_Op_Digest_Final_Compute`. The size of the digest is defined by macros of the form QAPI_CRYPTO_<ALG>_DIGEST_BYTES where ALG is the digest algorithm.

3.12.5.3 Cipher operations

- Allocate the digest operation and set the key.

- Call `qapi_Crypto_Op_Cipher_Init` to initialize the cipher operation.
- Update the ciphertext using `qapi_Crypto_Op_Cipher_Update`. (Optional – AES CBC NOPAD only).
- Compute the cipher text using `qapi_Crypto_Op_Cipher_Final`.
  The ciphers supported are AES CTR mode and AES CBC NO PAD. To get the length of the cipher text buffer that needs to allocated use the macro
  `QAPI_CRYPTO_AES_ENCRYPT_CIPHER_TEXT_BUFFER_SIZE_BYTES`.

NOTE: Because "AES_CBC_NOPAD" does not add padding, the plain text must be a multiple of the AES block size `QAPI_CRYPTO_AES_BLOCK_BYTES` (16 bytes).

3.12.5.4 Random number generation

Call `qapi_Crypto_Random_Get` to generate a pseudorandom number.

3.12.5.5 Authentication encryption operations

Authenticated Encryption with Associated Data (AEAD), in addition to encrypting the data, outputs a tag that be used for authentication. Additional Authenticated Data (AAD) that is only authenticated and not encrypted can optionally be provided.

The steps for encrypt and decrypt are similar except for the final step.

- Allocate the AEAD operation and set the key.
- Initialize the operation using qapi_Crypto_Op_AE_Init. This operation takes a nonce, which must be unique per operation. The nonce must be 12 bytes for AES GCM and ChaCha20. For AES CCM it must be >= 7 and <= 13 bytes. The tag must be 128 bits long for GCM and ChaCha20 and can be either 128, 64, or 32 bits for CCM.
- Call `qapi_Crypto_Op_AE_AAD_Update` to AAD. Subsequent calls to update after the first call is only supported for ChaCha20.

To encrypt:

- To encrypt the plain text call `qapi_Crypto_Op_AE_Encrypt_Final`. To get the size of the buffer to allocate for encryption use the macro
  `QAPI_CRYPTO_AES_ENCRYPT_CIPHER_TEXT_BUFFER_SIZE_BYTES` for AES GCM and CCM and the macro
  `QAPI_CRYPTO_CHACHA20_POLY1305_ENCRYPT_CIPHER_TEXT_BUFFER_SIZE_BYTES` for ChaCha20.

To decrypt:

- To decrypt the cipher text call `qapi_Crypto_Op_AE_Decrypt_Final`. Use the macro `QAPI_CRYPTO_AES_DECRYPT_PLAIN_TEXT_BUFFER_SIZE_BYTES` to get the size of the plain text buffer that needs to be allocated. The actual size of the plain text is set in the destLen parameter by the decrypt operation. For ChaCha20, use the macro,
  `QAPI_CRYPTO_CHACHA20_POLY1305_DECRYPT_PLAIN_TEXT_BUFFER_SIZE_BYTES`.

3.12.5.6 Key derivation

The key derivation algorithm allows the device to establish a shared secret with another party. Both parties have public and private parameters. Each side combines the parameters with the public parameters of the other party to derive a shared secret. What these parameters are and how they are combined to derive the shared secret depends on the algorithm. The mechanism by which the public parameters are shared between the two parties is left up to the application. For example, the parameters might be shared over a secure TLS connection. Diffie-Helman, Elliptic Curve Diffie-Helman, and Curve25519 are examples of key derivation algorithms.

Two password authentication key exchange (PAKE) algorithms are also supported − SRP and ECJPAKE. These two require both the parties to share a common password before running the key derivation algorithm. The key is derived using the password. The ECJPAKE algorithm is discussed in section 3.12.5.6.1.

Before running the key derivation operation, the public and private key pair must be stored as either a transient or persistent object (persistent object is not supported for all algorithms). The public key values of the other party are also required. The type of object required for each algorithm is listed in the table below.

Key pair object

Algorithm	Key pair object	Supported type
Diffie-Helmann (DH)	`QAPI_CRYPTO_OBJ_TYPE_DH_KEYPAIR_E`	Transient
Elliptic Curve Diffie-Helmann (ECDH)	`QAPI_CRYPTO_OBJ_TYPE_ECDH_KEYPAIR_E`	Transient or Persistent
Curve 25519	`QAPI_CRYPTO_OBJ_TYPE_CURVE25519_KEYPAIR_E`	Transient

To run the key derivation operation:

1. Allocate the key derivation operation using `qapi_Crypto_Op_Alloc`. The algorithm IDs are listed here.

Algorithm	Algorithm ID
Diffie-Helmann (DH)	`QAPI_CRYPTO_ALG_DH_DERIVE_SHARED_SECRET_E`
Elliptic Curve Diffie-Helmann (ECDH)	`QAPI_CRYPTO_ALG_ECDH_<CurveId>_E (The CurveId should match the curve of the ECDH keypair object)`
Curve 25519	`QAPI_CRYPTO_ALG_CURVE25519_DERIVE_SHARED_SECRET_E`

2. Call `qapi_Crypto_Op_Key_Set` with the first argument as the operation allocated in the first step, and second argument as the persistent or transient object representing the device's DH or ECDH keypair.
3. Derive the shared secret using the command `qapi_Crypto_Op_Key_Derive`. The attrs parameters is an array of attributes containing public key of the peer. The specific attributes depend on the algorithms listed here.

Algorithm	Attributes
Diffie-Helmann (DH)	One attribute of type, `QAPI_CRYPTO_ATTR_DH_PUBLIC_VALUE`

Algorithm	Attributes
Elliptic Curve Diffie-Helmann (ECDH)	Two attributes of type: QAPI_CRYPTO_ATTR_ECC_PUBLIC_VALUE_X and QAPI_CRYPTO_ATTR_ECC_PUBLIC_VALUE_Y
Curve 25519	One attribute of type, QAPI_CRYPTO_ATTR_CURVE25519_PUBLIC_VALUE_E

3.12.5.6.1 ECJPAKE algorithm

The ECJPAKE algorithm has a complex call flow when compared to the other key derivation algorithms. The two parties go through multiple rounds to establish the shared secret.

1. Allocate an ECJPAKE operation `qapi_Crypto_Op_Alloc` with the algorithm ID `QAPI_CRYPTO_ALG_ECJPAKE_E`.
2. Call `qapi_Crypto_Op_Key_Set` on the operation with the key being a transient object of type `QAPI_CRYPTO_OBJ_TYPE_GENERIC_SECRET_E` containing the shared password. The maximum password length is defined by `QAPI_CRYPTO_ECJPAKE_PASSWORD_MAX_BYTES`.
3. Allocate a transient object of type `QAPI_CRYPTO_OBJ_TYPE_ECJPAKE_ROUND1_PUBLIC_KEY_AND_ZKP_PAIR_E`, to hold the derived round one parameters.
4. Derive the round one parameters by calling `qapi_Crypto_Op_Intermediate_Key_Derive` with the previously allocated ECJPAKE operation, and the round one parameters object. The identity (`QAPI_CRYPTO_ATTR_ECJPAKE_LOCAL_IDENTITY_E`) and ECC curve (`QAPI_CRYPTO_ATTR_ECC_CURVE_E`) are inputs. The round one parameters object is populated with the round one parameters.
5. Call qapi_Crypto_Obj_Buf_Attrib_Get on the round one parameters object for the public round one parameters QAPI_CRYPTO_ATTR_ECJPAKE_ROUND1_PUBLIC_KEY_1_E, QAPI_CRYPTO_ATTR_ECJPAKE_ROUND1_ZKP_EPHEMERAL_PUBLIC_KEY_1_E, and QAPI_CRYPTO_ATTR_ECJPAKE_ROUND1_ZKP_SIGNATURE_1_E, QAPI_CRYPTO_ATTR_ECJPAKE_ROUND1_PUBLIC_KEY_2_E, QAPI_CRYPTO_ATTR_ECJPAKE_ROUND1_ZKP_EPHEMERAL_PUBLIC_KEY_2_E, and QAPI_CRYPTO_ATTR_ECJPAKE_ROUND1_ZKP_SIGNATURE_2_E. These must be shared with the remote party.
6. Allocate a transient object of type `QAPI_CRYPTO_OBJ_TYPE_ECJPAKE_ROUND2_PUBLIC_KEY_AND_ZKP_E` to hold the derived round two parameters.
7. Derive the round one parameters by calling `qapi_Crypto_Op_Intermediate_Key_Derive` with the previously allocated ECJPAKE operation, and round two parameters object. The round one parameters of the remote party as well as the identity of the remote party (`QAPI_CRYPTO_ATTR_ECJPAKE_REMOTE_IDENTITY_E`) are input as an array of attributes. When qapi_Crypto_Op_Intermediate_Key_Derive completes, the round two parameters transient object is populated.
8. Call qapi_Crypto_Obj_Buf_Attrib_Get to get the public round two parameters to share with the remote party. These attributes must be shared − QAPI_CRYPTO_ATTR_ECJPAKE_ROUND2_PUBLIC_KEY_E, QAPI_CRYPTO_ATTR_ECJPAKE_ROUND2_ZKP_EPHEMERAL_PUBLIC_KEY_E, and QAPI_CRYPTO_ATTR_ECJPAKE_ROUND2_ZKP_SIGNATURE_E.

9. Call `qapi_Crypto_Op_Key_Derive` to obtain the shared secret. The round two parameters of the remote party as input as an attribute array to this function. The derived_key_hdl is a handle to a transient object of type QAPI_CRYPTO_OBJ_TYPE_GENERIC_SECRET_E which has a key length of QAPI_CRYPTO_ECJPAKE_PASSWORD_MAX_BYTES. This object holds the derived secret.

3.12.5.7 MAC operations

1. After allocating the operation and setting the key, call `qapi_Crypto_Op_Mac_Init` to initialize the hash operation.
2. Update the MAC using `qapi_Crypto_Op_Mac_Update` (Optional).
3. Compute the final MAC using `qapi_Crypto_Op_Mac_Final_Compute`. The size of the MAC is defined by macros of the form `QAPI_CRYPTO_HMAC_<ALG>_MAC_BYTES` where ALG is the HMAC algorithm.

3.12.5.8 Asymmetric sign and verify operations

To sign:

1. Create a digest of the message.
2. After allocating the operation and setting the key, call `qapi_Crypto_Op_Sign_Digest` to sign the digest.
   For ECDSA, use the macro `QAPI_CRYPTO_ECDSA_SIGNATURE_BUFFER_SIZE_BYTES` to get the size of the buffer that holds the signature.
   For RSA, use `QAPI_CRYPTO_RSA_SIGNATURE_BUFFER_SIZE_BYTES`. Note that for ECDSA there are multiple standards for the signature format. We use the ASN.1 format.

To verify:

1. Create a digest of the message.
2. After allocating the operation and setting the key, call `qapi_Crypto_Op_Verify_Digest` to sign the digest. ECDSA signatures must be in ASN.1 format.

3.12.5.9 Asymmetric encryption operations

1. After allocating the operation and setting the key, call `qapi_Crypto_Op_Asym_Encrypt` to encrypt plain text. The supported encryption algorithms are RSA with PKCS 1.5 padding or RSA with no padding.

   For RSA with PKCS 1.5 padding, the plain text must be less than or equal to the RSA key size. For RSA with no padding, the plain text must be exactly equal to the RSA key size. Use the macro `QAPI_CRYPTO_RSA_ENCRYPT_CIPHER_TEXT_BUFFER_SIZE_BYTES` to get the size of the cipher text buffer that needs to be allocated.
2. Call `qapi_Crypto_Op_Asym_Decrypt` to decrypt cipher text into plain text. The cipher text must be encrypted with RSA with PKCS 1.5 padding or with no padding (depending on the algorithm selected). Use the macro `QAPI_CRYPTO_RSA_DECRYPT_PLAIN_TEXT_BUFFER_SIZE_BYTES` to get the size of the plain text buffer that needs to be allocated.

3.12.5.10 Secure utilities

Use `qapi_Crypto_Secure_Memzero` to zero any sensitive data from memory. As opposed to regular memzero, this call is ensured not to be optimized out by the compiler.

3.12.6 Secure ED25519 keypair generation and signing

The ED25519 module provides secure ED25519 key pair generation and signing operations.

The key pairs are generated and stored using the `qapi_Ed25519_Generate_Key_Pair() QAPI` function. The actual generation and storage of the keypair happens inside the Trusted Execution Environment (TEE), such that the host CPU does not have means to access the private key. On successful return from this function, the public key is returned to the caller. Later, this public key must be used with crypto verify operation to verify messages that were signed with the corresponding private key.

The ED25519 signing operation using the previously generated ED25519 keypair is performed using the qapi_Ed25519_Sign function. This function is executed inside TEE, because the private key necessary for generating the signature is securely stored inside TEE and never leaves it.

3.13 Host-target Communications (HTC)

The core library provides an HTC_Slave API to support communication with an external "Host" or "Master" system. This API is currently supported over SDIO and SPI interconnects, though it is sufficiently general to support additional Host-Target interconnects in the future.

APIs are provided to:

- Initialize, configure, start, stop, pause, and resume communications
- Register handlers for various events, including "received a buffer from Host" and "sent a buffer to Host" events
- Send and receive data, currently limited to under 2KB

Communication takes place to/from HTC "endpoints" which might be related to underlying characteristics of the interconnect hardware or interconnect configuration or might reflect intended software usage of the interconnect. In addition, the HTC_Slave API provides for expansion to support *multiple* Hosts, though only a *single* Host is currently supported.

An external Host/Master may be any system that adheres to the *HTC Protocol*. This includes, for example, an external Linux x86 system or an external MCU running an arbitrary RTOS. It is expected that a messaging layer is built on top of the generic HTC communication layer so that OEM software running on the external Host may communicate with OEM software running on the QCA402x.

4 QCA402x application development

4.1 QCA402x SDK compilation model

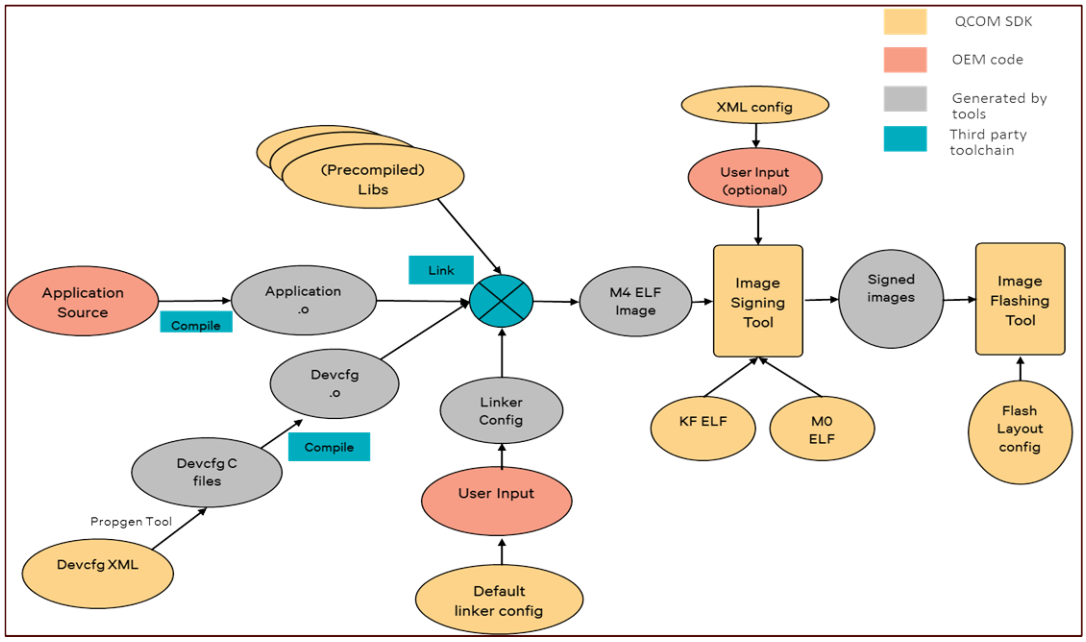


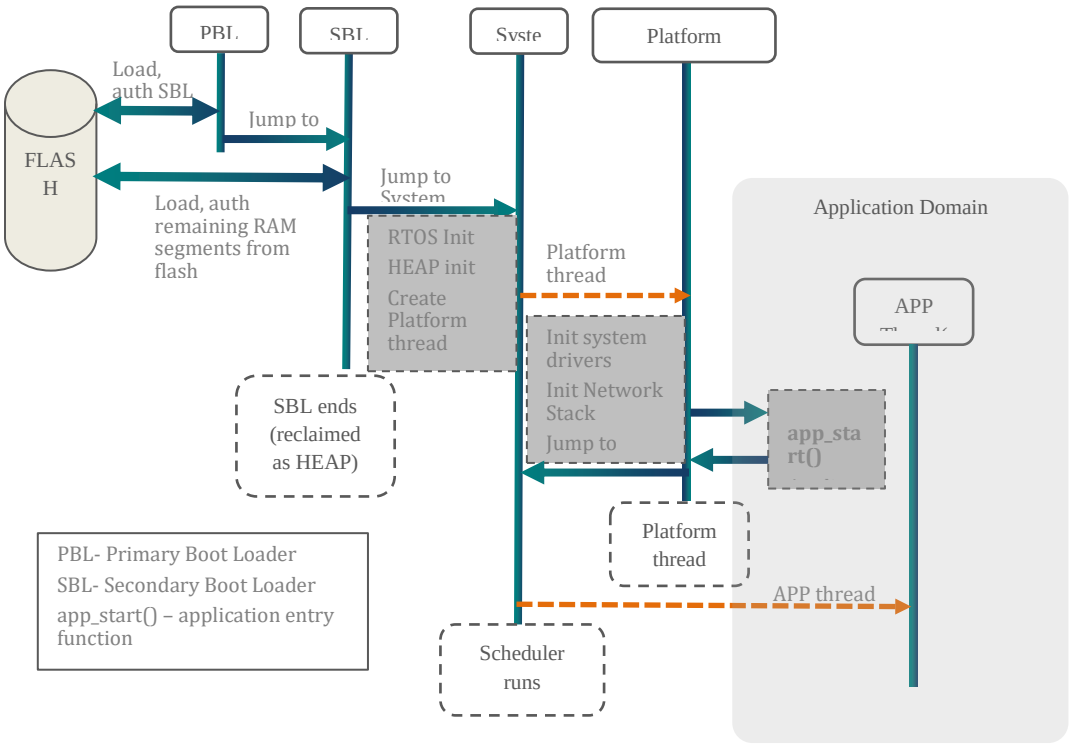
Figure 4-1 QCA402x SDK compilation model

Figure 4-1 shows the compilation model with application development flow on QCA402x SDK. An application developer can configure following components as user entries:

- Application Source: For application code sturcutre, refer to Helloworld demo section in *QCA402x Development Kit User Guide* (80-YA121-140).
- Device Configuration: Feature to tune system parameters at runtime. Master device configuration XML file is copied from \build\tools\devcfg to application\src\export directory by build scripts. Python-based propgen tool generates C files from the XML file. See section 4.3.1.
- Platform Configuration: Feature to tune system parameters at compile time. Master platform configuration file is copied from quartz\platform\export to application\src\export directory by build scripts. See section 4.3.1.
- Linker Configuration: An OEM has an option to place code into the following regions such as FOM RAM, FOM XIP, or SOM RAM. SDK includes python scripts \build\scripts\linkerScripts that generate linker configuration files based on user input. The input to the linker script is a config file provided in the sample application directory. For details, see section 4.3.3.

- Image Signing (Optional): Image signing tool is integrated in SDK. For the image signing configuration, input parameters are provided to the image signing tool. For more information, refer to Secure Boot on QCA402x (80-YA121-144) document.

4.2 QCA402x boot flow



4.3 Configuration and programming

4.3.1 Configuring an application

Two types of configuration options are provided in the SDK:

Run-time configuration through DevCfg

The SDK contains a Python-based device configuration utility (PropGen), that provides a mechanism to tune various system parameters at run-time. A pair of XML files containing system configuration parameters are provided.

Free-RTOS

```
target/build/tools/devcfg/freertos/DevCfg_master_devcfg_out_cdb.xml
target/build/tools/devcfg/freertos/DevCfg_master_fom_out_cdb.xml
```

ThreadX

```
target/build/tools/devcfg/freertos/DevCfg_master_devcfg_out_cdb.xml
target/build/tools/devcfg/freertos/DevCfg_master_fom_out_cdb.xml
```

These files are then installed to the application export directory as a pre-build step. Refer to *QCA402x Development Kit User Guide* (80-YA121-140).

```
target/quartz/demo/QCLI_Demo/src/export/DevCfg_master_devcfg_out_cdb.xml
target/quartz/demo/QCLI_Demo/src/export/DevCfg_master_fom_out_cdb.xml
```

An OEM can edit these XML files based on product requirements and then run the PropGen tool to generate C source files.

The following example generates four source files from the two XML files:

```
python %RootDir%/build/tools/devcfg/propgen.py --XmlFile=
%SrcDir%/DevCfg_master_devcfg_out.xml
--DirName=%SrcDir%/export --ConfigFile=%SrcDir%/DALConfig_devcfg.c
--DevcfgDataFile=%SrcDir%/devcfg_devcfg_data.c --
ConfigType=%CHIPSET_VARIANT%_devcfg_xml

python %RootDir%/build/tools/devcfg/propgen.py --
XmlFile=%SrcDir%/export/DevCfg_master_fom_out.xml --DirName=%SrcDir%/export
--ConfigFile=%SrcDir%/export/DALConfig_fom.c --
DevcfgDataFile=%SrcDir%/export/devcfg_fom_data.c --
ConfigType=%CHIPSET_VARIANT%_fom_xml

Here-
RootDir- target
SrcDir- target/quartz/demo/QCLI_Demo/src/export/
CHIPSET_VARIANT – qca4020, qcq4024
```

The preceding commands generate the following source files:

```
DALConfig_devcfg.c
DALConfig_fom.c
devcfg_devcfg_data.c
devcfg_fom_data.c
```

These source files must be compiled by the OEM along with the application source code and linked to the final ELF image. Qualcomm modules extract the configuration parameters at run-time and apply the selected configuration accordingly.

Compile time configuration

QCA4020 SDK also contains platform configuration files that allow disabling of certain optional driver modules.

Read-only location of platform configuration files.

```
target\quartz\platform\export\platform_oem.h
target\quartz\platform\export\platform_oem.c
target\quartz\platform\export\platform_oem_som.c
target\quartz\platform\export\platform_oem_mom.c
```

These files are then installed to the application export directory as a pre-build step.

Refer to *QCA402x Development Kit User Guide* (80-YA121-140). The OEM may optionally choose the edit `platform_oem.h` to disable any unwanted driver modules.

NOTE: The files must be compiled by OEM toolchain.

For example, Disable "Diag" feature at compile time:

- Edit SRC-IOE-SDK\quartz\QCLI_Demo\src\export\platform_oem.h
- Un-define `DIAG_INIT_COLD` macro
- Rebuild the demo. The resulting elf file do not initialize "Diag" feature.

4.3.2 GPIO customization

GPIO on QCA402x can be configured for various functionalities depending on the user cases. Some of the commonly used peripherals are SPI, UART, SDIO, and I2C/I2S. In the device configuration XML file, GPIO pins must be configured properly based on hardware configuration.

For the supported GPIO configuration options, see Appendix A.

4.3.2.1 Configuring Peripheral Bus GPIO

In `DevCfg_master_fom_out.xml`, OEM can also configure GPIO for peripheral bus according to the hardware configuration.

The following example shows HS-UART configuration on OEM board.

HS_UART	Reference Board			OEM Board		
	GPIO	Func_Sel	I/O	GPIO	Func_Sel	I/O
QCA402x_UART_TX	GPIO 60 (0x003C)	4	Output	GPIO 15 (0x000F)	1	Output
QCA402x_UART_RTS	GPIO 16 (0x0010)	1	Output	GPIO 16 (0x0010)	1	Output
QCA402x_UART_CTS	GPIO 59 (0x003B)	2	Input	GPIO 14 (0x000E)	1	Input

UART Configuration

```
<!--
GPIO configuration calculation
GPIO DIR values
   GPIO_INPUT = 0x0
   GPIO_OUTPUT = 0x1
GPIO_PULL values
   GPIO_NO_PULL    = 0,
   GPIO_PULL_DOWN  = 0x1,
   GPIO_PULL_UP    = 0x2,
GPIO_DRV_STRENGTH values
   GPIO_2MA     = 0,
   GPIO_4MA     = 0x1,
   GPIO_6MA     = 0x2,
   GPIO_8MA     = 0x3,
   GPIO_10MA    = 0x4,
   GPIO_12MA    = 0x5,
   GPIO_14MA    = 0x6,
```

```
   GPIO_16MA    = 0x7,
GPIO configuration =  (GPIO_NUM           & 0xFF) << 0x10 |
                      (GPIO_FS_VAL        &  0xF) <<  0xC |
                      (GPIO_DRV_STRENGTH  &  0xF) <<  0x8 |
                      (GPIO_PULL          &  0xF) <<  0x4 |
                      (GPIO_DIR           &  0xF)
-->
```

Reference board

```
   <device id="0x0200000f">
      <props id="0x20001"            id_name="UART_PROP_STRUCT_ID"
oem_configurable="false" helptext="Internal uart device
structure"   type="0x00000012">  uart_second_port  </props>
      <!-- UART open gpio configurations -->
      <props
id="0x20002"   id_name="UART_PROP_GPIO_TX_PU_CONF_ID"  oem_configurable="tr
ue"  helptext="GPIO configuration"
type="0x00000002">   0x003C4021          </props>
      <props
id="0x20003"   id_name="UART_PROP_GPIO_RX_PU_CONF_ID"  oem_configurable="tr
ue"  helptext="GPIO configuration"
type="0x00000002">   0x00111020          </props>
      <props id="0x20004"  id_name="UART_PROP_GPIO_RFR_PU_CONF_ID"
oem_configurable="true"  helptext="GPIO configuration"
type="0x00000002">   0x00101021          </props>
      <props id="0x20005"  id_name="UART_PROP_GPIO_CTS_PU_CONF_ID"
oem_configurable="true"  helptext="GPIO configuration"
type="0x00000002">   0x003B2020          </props>
      <!-- UART close gpio configurations -->
      <props
id="0x20006"   id_name="UART_PROP_GPIO_TX_PD_CONF_ID"  oem_configurable="tr
ue"  helptext="GPIO configuration"
type="0x00000002">   0x003C0020          </props>
      <props
id="0x20007"   id_name="UART_PROP_GPIO_RX_PD_CONF_ID"  oem_configurable="tr
ue"  helptext="GPIO configuration"
type="0x00000002">   0x00110020          </props>
      <props id="0x20008"  id_name="UART_PROP_GPIO_RFR_PD_CONF_ID"
oem_configurable="true"  helptext="GPIO configuration"
type="0x00000002">   0x00100020          </props>
      <props id="0x20009"  id_name="UART_PROP_GPIO_CTS_PD_CONF_ID"
oem_configurable="true"  helptext="GPIO configuration"
type="0x00000002">   0x003B0010          </props>
   </device>
```

OEM board

```
 <device id="0x0200000f">
      <props id="0x20001"            id_name="UART_PROP_STRUCT_ID"
oem_configurable="false" helptext="Internal uart device
structure"   type="0x00000012">  uart_second_port  </props>
      <!-- UART open gpio configurations -->
      <props
id="0x20002"   id_name="UART_PROP_GPIO_TX_PU_CONF_ID"  oem_configurable="tr
ue"  helptext="GPIO configuration"
type="0x00000002">   0x000F1021          </props>
      <props
id="0x20003"   id_name="UART_PROP_GPIO_RX_PU_CONF_ID"  oem_configurable="tr
ue"  helptext="GPIO configuration"
type="0x00000002">   0x00111020          </props>
      <props id="0x20004"  id_name="UART_PROP_GPIO_RFR_PU_CONF_ID"
oem_configurable="true"  helptext="GPIO configuration"
type="0x00000002">   0x00101021          </props>
      <props id="0x20005"  id_name="UART_PROP_GPIO_CTS_PU_CONF_ID"
oem_configurable="true"  helptext="GPIO configuration"
type="0x00000002">   0x000E1020          </props>
      <!-- UART close gpio configurations -->
      <props
id="0x20006"   id_name="UART_PROP_GPIO_TX_PD_CONF_ID"  oem_configurable="tr
ue"  helptext="GPIO configuration"
type="0x00000002">   0x000F0020          </props>
      <props
id="0x20007"   id_name="UART_PROP_GPIO_RX_PD_CONF_ID"  oem_configurable="tr
ue"  helptext="GPIO configuration"
type="0x00000002">   0x00110020          </props>
      <props id="0x20008"  id_name="UART_PROP_GPIO_RFR_PD_CONF_ID"
oem_configurable="true"  helptext="GPIO configuration"
type="0x00000002">   0x00100020          </props>
      <props id="0x20009"  id_name="UART_PROP_GPIO_CTS_PD_CONF_ID"
oem_configurable="true"  helptext="GPIO configuration"
type="0x00000002">   0x000E0010          </props>
   </device>
```

4.3.2.2 Configure external PTA GPIO

QCA402x can operate as External PTA master or slave. GPIO 5, 6, and 7 are reserved for the external PTA interface such as WLAN_ACTIVE, BT_ACTIVE and BT_PRIORITY. The GPIOs can be interfaced directly with the external chipset. Ensure that the I/O voltage on two chipsets is at the same level. The GPIOs must be configured according to PTA master or slave mode:

PTA Master Mode

Signal Name	QCA402x GPIO #	Motherboard Pin	I/O (QCA402x)
WLAN_ACTIVE	5	1, Header J15	Output
BT_ACTIVE	6	3, Header J15	Input
BT_PRIORITY	7	5, Header J15	Input

Signal Name	QCA402x GPIO #	Motherboard Pin	I/O (QCA402x)
GND	-	2, Header J15	-

PTA Slave Mode

Signal Name	QCA402x GPIO #	Motherboard Pin	I/O (QCA402x)
BT_ACTIVE	5	1, Header J15	Output
WLAN_ACTIVE	6	3, Header J15	Input
BT_PRIORITY	7	5, Header J15	Output
GND	–	2, Header J15	–

QCA402x SDK contains commands to configure the external PTA mode with GPIOs. The following example shows how to set external PTA master and slave mode through the QCLI demo commands:

PTA master mode

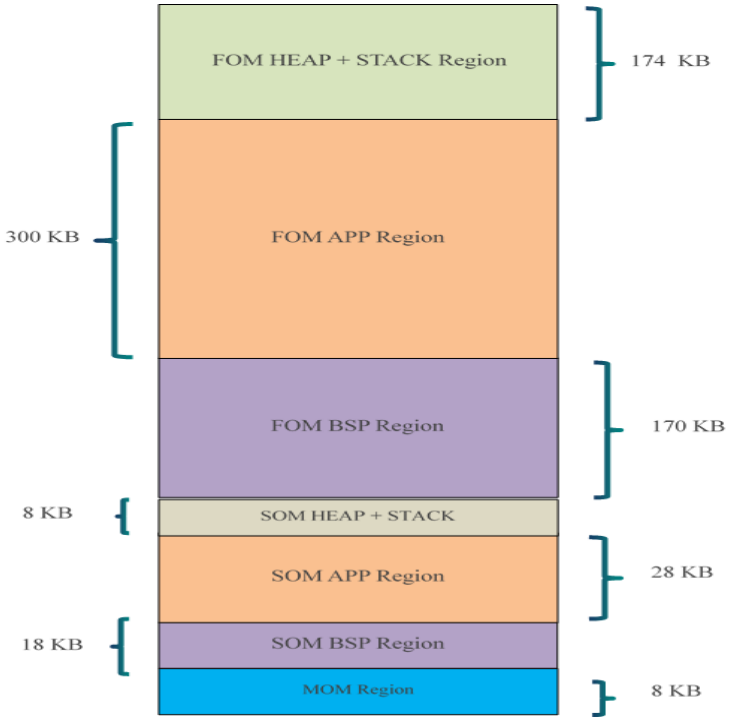
```
Coex EPTAGPIOEnable 2
Coex ConfigureAdvanced 3 0
```

PTA slave mode

```
Coex EPTAGPIOEnable 1
Coex ConfigureAdvanced 1 0
```

4.3.3 Code placement

QCA402x memory map is is split into multiple regions with different power profiles.



An OEM has an option to place code into the following regions:

- FOM RAM: For time critical code running in full power mode.
- FOM XIP: For non-time critical code running in full power mode.
- SOM RAM: For code running in low power (sensor) mode.

To assist with the preceding placement options, SDK includes Python scripts that generate linker configuration files based on user input.

The scripts are located at: `target/build/scripts/linkerScripts`

The input to the linker script is a config file provided in the sample application directory. Location: `target/quartz/demo/QCLI_Demo/build/gcc/app.config`

Each line in the config file specifies the placement parameters for an application object file. OEM must update the config file for all application object files.

NOTE: If an object file is not explicitly placed in a region, it ends up in the default region (FOM RAM region).

Example 1: Placing main.o in SOM RAM region:

"**main.o APPS SOM RAM**" places main.o in SOM Application RAM region

Example 2: Placing app.o in FOM XIP region:

"**app.o APPS FOM XIP**" places app.o in FOM Application XIP region

The following steps generate a "`quartz.ld`" linker configuration file from app.config input file. See the Makefile for example:

1. Generate app.placement file from app.config and system placement files

```
python %LinkerScriptDir%\CreateAppPlacementFile.py %RootDir%\bin\cortex-m4\threadx\sys.placement %RootDir%\bin\cortex-m4\threadx\cust.placement app.config app.placement
```

2. Create linker configuration file

```
python %LinkerScriptDir%\MakeLinkerScript.py %RootDir%\bin\cortex-m4\threadx\DefaultTemplateLinkerScript.ld app.placement %LIBSFILE% > %LINKFILE%

RootDir- target
LinkerScriptDir - target/build/scripts/linkerScripts
LIBSFILE – String with all system libs and object files used by application
LINKFILE – output linker configuration file (quartz.ld for sample application)
```

4.3.4 Resize application memory

QCA402x has 328 KB of RAM dedicated for customer applications. In addition to this, OEMs can choose to place their code in XIP region. OEM can change the distribution between code and data RAM in 128 KB increments.

The default distribution of Application data and code RAM is as follows.

Code RAM: 232 KB (RAM_FOM_APPS_RO_MEMORY region)

Data RAM: 64 KB (RAM_FOM_APPS_DATA_MEMORY region)

Example 1: To increase the data memory (RAM_FOM_APPS_DATA_MEMORY) by 128 KB, make the following changes:

1. To increase data memory (RAM_FOM_APPS_DATA_MEMORY), decrease the code memory (RAM_FOM_APPS_RO_MEMORY) by the same amount. Make the following changes in DefaultTemplateLinkerScript.ld script

```
RAM_FOM_APPS_RO_MEMORY (Rx) : ORIGIN = 0x10046000, LENGTH = 0x3a000
RAM_FOM_APPS_DATA_MEMORY (W)  : ORIGIN = 0x10080000, LENGTH = 0x10000
```

   to

```
RAM_FOM_APPS_RO_MEMORY (Rx) : ORIGIN = 0x10046000, LENGTH = 0x1a000
 RAM_FOM_APPS_DATA_MEMORY (W) : ORIGIN = 0x10060000, LENGTH = 0x30000
```

2. By default, the Data Execution Prevention (DEP) is enabled on QCA402x. To make changes to code and data memory regions, adjust the DEP configuration. Modify DevCfg_master_devcfg_out.xml file to adjust DEP configuration region.

Th application RAM regions (RAM_FOM_APPS_DATA_MEMORY, RAM_FOM_APPS_RO_MEMORY) belong to MPU region 2 (row 3 highlighted in the code snippet)

```
    <!-- All the data is in Little Endian Format -->
     <!-- FORMAT: -->
     <!-- DEP_region_start_address - 4 bytes -->
     <!-- DEP_region_size - 4 bytes -->
     <!-- DEP_region_index - 1 byte -->
     <!-- DEP_sub_region_mask - 1 byte (set bit to '1' for disabling the
sub-region) -->
     <!-- DEP_access_control - 1 byte (0x6 for RO, 0x3 for RW) -->
     <!-- XN - 1 byte -->
     <!-- 64MB ROM region          = --> 0x00, 0x00, 0x00, 0x00,  0x00,
0x00, 0x00, 0x04, 0x00, 0x00, 0x06, 0x00,
     <!-- 1MB RAM region           = --> 0x00, 0x00, 0x00, 0x10,  0x00,
0x00, 0x10, 0x00, 0x01, 0x00, 0x03, 0x01,
     <!-- FOM Code and Data region = --> 0x00, 0x00, 0x00, 0x10,  0x00,
0x00, 0x10, 0x00, 0x02, 0xF1, 0x06, 0x00,
     <!-- FOM APPS region          = --> 0x00, 0x00, 0x08, 0x10,  0x00,
0x00, 0x01, 0x00, 0x03, 0xFF, 0x06, 0x00,
     <!-- SOM Code and Data region = --> 0x00, 0x40, 0x00, 0x10,  0x00,
0x40, 0x00, 0x00, 0x04, 0x01, 0x06, 0x00,
     <!-- SOM APPS and HEAP        = --> 0x00, 0x80, 0x00, 0x10,  0x00,
0x80, 0x00, 0x00, 0x05, 0xE0, 0x06, 0x00,
     <!-- MOM region               = --> 0x00, 0x10, 0x00, 0x10,  0x00,
0x10, 0x00, 0x00, 0x06, 0xC7, 0x06, 0x00,
<!-- SBL region               = --> 0x00, 0x00, 0x0A, 0x10,  0x00, 0x00,
0x01, 0x00, 0x07, 0x00, 0x3, 0x01,
```

Every 128 KB block that needs to be changed requires corresponding adjustment to DEP_sub_region_mask byte (highlighted in red). Each bit in DEP_sub_region_mask corresponds to one 128 KB block. Setting a bit changes the block from code to data. Example:

making it 0xF9 if 128 KB is moved from RO to DATA, 0xFD if 256 KB from RO to DATA is moved and so on.

Heap starts at the end of APP data region.

In GCC, linker script automatically adjusts start of heap address based on application processor data region usage.

`Resizing FreeRTOS Heap`

FreeRTOS requires a dedicated memory pool used for allocating RTOS-specific elements such as task stack. OEMs might adjust this allocation based on their needs by following the steps.

`cd to "./FreeRTOS/2.0/FreeRTOS/Demo/QUARTZ" directory. Edit FreeRTOSConfig.h, change configTOTAL_HEAP_SIZE to the appropriate value. Rebuild FreeRTOS library. Refer to` *QCA402x Development Kit User Guide* `(80-YA121-140).`

`cd to target/bin/cortex-m4/freertos. Edit DefaultTemplateLinkerScript.ld, change RTOS_HEAP_SIZE to match configTOTAL_HEAP_SIZE from step 1. Build the application. The new FreeRTOS heap value is applied.`

4.3.5 RAM dump collection and debugging

The RAM dump collection mode is configurable in device configuration file "`DevCfg_master_devcfg_out.xml`".

- Enable/disable RAM dump collection mode in "PLATFORM RAMDUMP ENABLED"

```
<driver name="platform">
  <device id="0x02000006">
      == snip ==
    <props id="7" id_name="PLATFORM RAMDUMP ENABLED"
oem_configurable="true" helptext="Enable or Disable Ramdump. 1--Enabled, 0--Disabled"
type="0x00000002">
      1
    </props>
      == snip ==
  </device>
</driver>
```

- Configure RAM dump method through USB/flash in "PLATFORM RAMDUMP CONFIG"

```
<driver name="platform">
  <device id="0x02000006">
      == snip ==
    <props id="11" id_name="PLATFORM RAMDUMP CONFIG" oem_configurable="true"
helptext="Configure the RAM Dump. " type="0x00000002">
        <!-- Mask - RRRRRRRT -->
        <!-- Where bits in 0xT represent following -->
        <!-- Bit 0: If set, enable the RAM dump via Uart/USB support otherwise disabled  -->
      <!-- Bit 1: If set, enable the RAM dump on QSPI Flash support otherwise disabled -->
      <!-- Bit 2 and Bit 3 are reserved for future use.                    -->
      0x00000003
    </props>
```

```
  </device>
</driver>
```

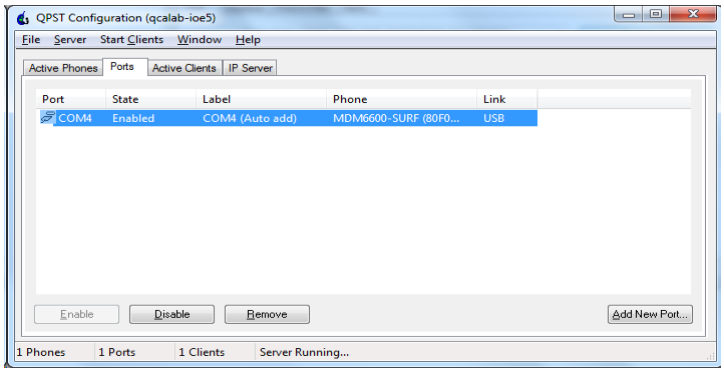
When watchdog reset happens, the RAM dump collection operates according to the device configuration as given here.

RAM dump collection mode		Expected operation when watchdog reset happens
PLATFORM RAMDUMP ENABLED	PLATFORM RAMDUMP CONFIG	
0	x	System is reset.
1	1	System waits for USB connection in RAM dump mode.
1	2	RAM dump is stored into flash and the system is reset.
1	3	RAM dump is stored into flash and system waits for USB connection in the RAM dump mode.

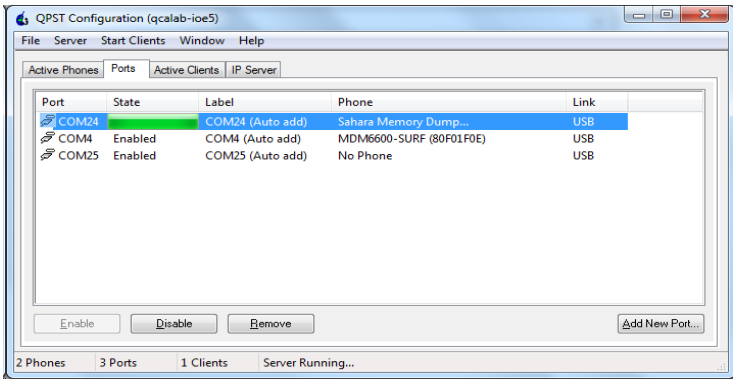
4.3.6 RAM dump collection procedure through USB

When `PLATFORM RAMDUMP CONFIG` sets bit0, the system waits for USB connection in the ram dump mode. The RAM dumps are collected by a PC based tool − QPST (as part of QDART_CONN) – available for download at https://createpoint.qti.qualcomm.com/tools/#. The dumps are collected over USB port (J6) on CDB2x board.

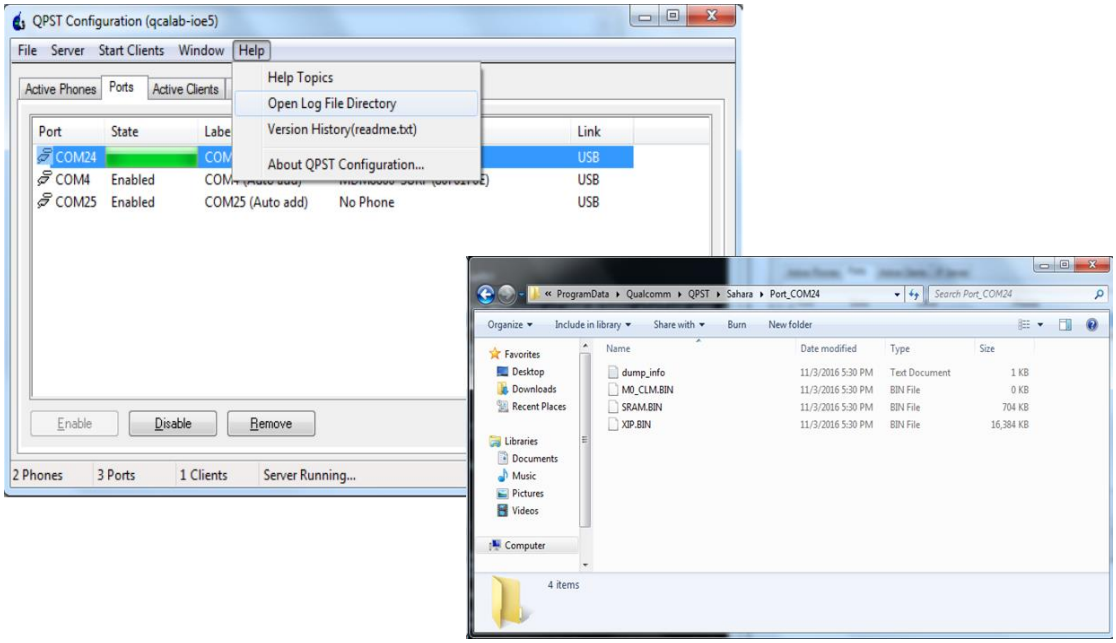
1. Connect a micro USB cable and start QPST configuration.
2. QPST configuration detects the COM ports.



3. If there is a crash, a watchdog reset triggers RAM dump generation and QPST automatically collects the dump over the newly enumerated USB port.



4. The M4, M0, and XIP dump files are available at the location − (C:\ProgramData\Qualcomm\QPST\Sahara).



4.3.7 Collect RAM dump stored in flash memory

When the `PLATFORM RAMDUMP CONFIG` mode sets bit 1, the system in RAM dump mode stores RAM to flash. After reboot, the system can upload the RAM dump stored in flash memory to the specific network server.

1. If a crash happens, a watchdog reset triggers RAM dump to be stored in flash memory.
2. After reboot, connect WLAN to the specific network server, and upload the RAM dump.

The supported commands for demonstration are:

Server_type: FTP

IP_version: v4

Parameter Name	Type/Range	Description
Server_type	String	Protocol for upload. Only FTP is supported
Ip_version	String	IP version. Only v4 is supported.

Parameter Name	Type/Range	Description
Ftps_ip_address	String	FTP server's IP address. Only IPv4 addresses are supported.
Login_name	String	FTP login account name
Login_password	String	FTP login account password
Ramdump_path	String	Optional. Directory on FTP server to locate RAM dump files. Directory under the root is supported.
ftpc_data_port	Integer	Optional. Data port for FTP client
ftps_cmd_port	Integer	Optional. Command port for FTP server
Ramdump_encryption	Integer/0,1	Optional. No encryption is supported yet.

Example: `platform ftp v4 192.168.1.11 username password dir`

4.3.8 RAM dump analysis

For RAM dump analysis, QCA402x SDK provides GNU debugger (GDB) scripts dumpserver.py and app_ramdump.gdbinit at `/target/quartz/gdb`. The GDB scripts load the dump file and obtain the pc and lr registers from the coredump data structure.

GDB requirements

- Must be built with Arm support.
- Should include a fix that allows backtraces to work properly on QCA402x binaries.
- Must include "Component: Arm Compiler" in symtab.c::arm_idents.
- Must include **python** support.
- The GDB python support files must be available in the expected locations on the system by setting the system environment variables.

  Example:

```
set PYTHONHOME=C:\Python276
set PYTHONPATH=C:\Python276\Lib
set PATH=%PYTHONHOME%;%PATH%
```

- Locate dump files and M4 image file at `/target/quartz/gdb`
  - RAM dump files: SRAM.BIN, M0_CLM.BIN, and XIP.BIN
  - M4 image elf file: Quartz.elf

To debug the RAM dump:

1. Run "set SDK=<path_to_sdk_root>" at `/target/quartz/gdb`. The path must include a forward slash and not back slash.
2. Run GDB scripts, "gdb -x app_ramdump.gdbinit Quartz.elf" in the command prompt. The script automatically starts dumpserver.py, which is used to access contents of SRAM.BIN and XIP.BIN
3. The scripts load dump and symbol files. The user can start GDB debugging session. For useful GDB commands, see section *Debugging through GDB* in *QCA402x Development Kit User Guide (*80-YA121-140).

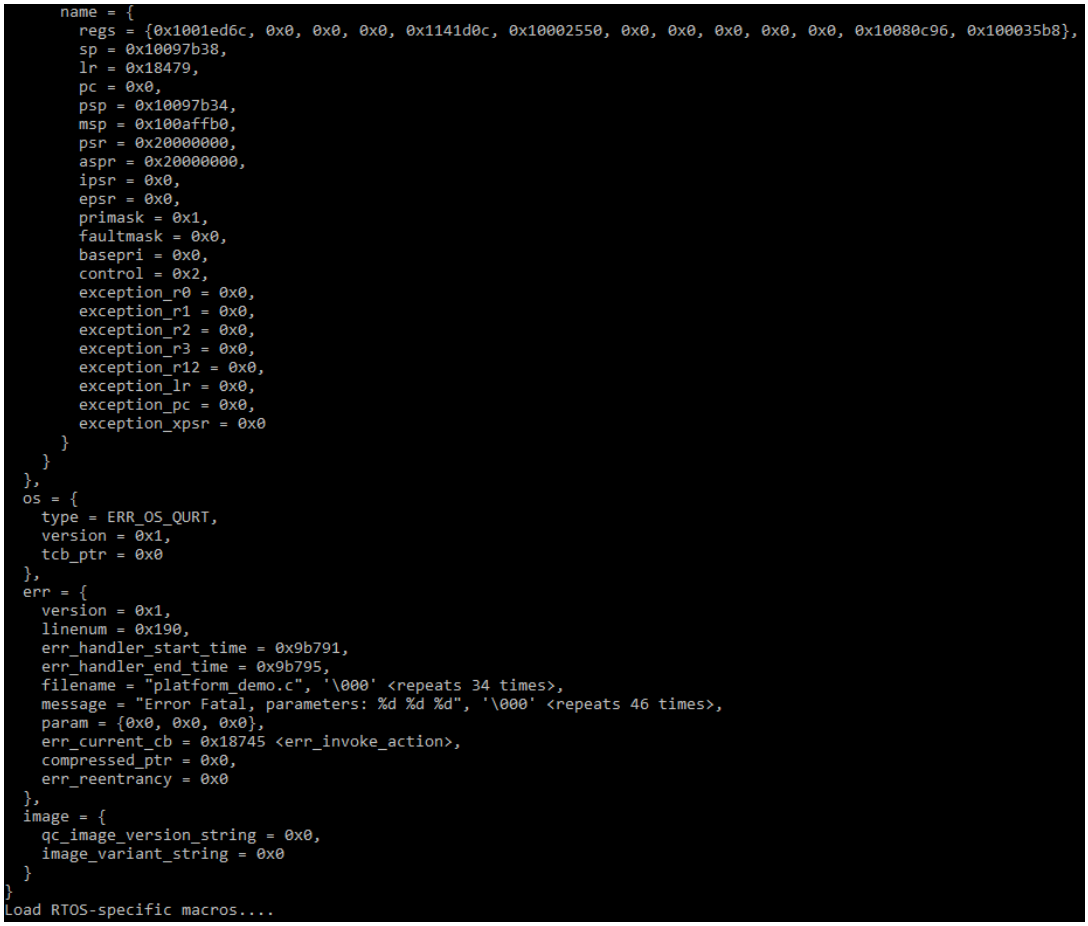


Figure 4-2 Start RAM dump debugging on GDB client

4.3.9 Image encryption

QCA402X SDK includes tools for image encryption. These tools are available at:
`target/build/scripts/elf_segment_encryption`

An image encryption tool requires image encryption key. A configuration file is also provided to generate the image encryption key:
`target/quartz/mfg/ROT/tools/gen_kdf_pwd.py`
`target/quartz/mfg/ROT/tools/kdf_config.xml`

Edit the configuration file to select image encryption operation and change parameters such as:

- op_code (operation code: 0x0A to generate image encryption key)
- oem_id (OEM identification for image encryption, matched in OTP)
- model_id (model identification for image encryption, matched in OTP)
- mid_id (machine identification: 1 for M4)
- otp_encryp_key (hardware encryption key, matched in OTP)
- dbg_enable (JTAG debug mode, matched in OTP)
- sw_input (fixed, should be F762C318828B32E5D1328C8130430481)

For a complete list of parameters, refer to build scripts.

The following example generates encrypted M4 images:

```
Windows-
python %SCRIPTDIR%\elf_segment_encryption\elf_encrpyt.py  -p
output\%PROJECT%.elf -k %CFG_ENCRYPT_KEY% -a
%SectoolsDir%\bin\WIN\crypto_cbc.exe -c
%SCRIPTDIR%\elf_segment_encryption\config.json -o output\%PROJECT%.elf

Linux-
python $(SCRIPTDIR)/elf_segment_encryption/elf_encrpyt.py  -p
$(OUTDIR)/$(PROJECT).elf -k $(CFG_ENCRYPT_KEY) -a openSSL -c
$(SCRIPTDIR)/elf_segment_encryption/config.json -o $(OUTDIR)/$(PROJECT).elf
```

For more information on image encryption, refer to *Enable secure boot and Image encryption in the QCA402x* (80-YA121-144) document.

4.3.10 Flash programming

To execute firmware, it must be programmed onto the flash memory of the device. Several tools in the SDK are used in the flashing process:

`gen_part_table.py` helps in creation of an XML file, "partition_table" that describes the contents of an Image Set. In other words, it describes which PC files must be programmed onto QCA402x flash. For instance, if an M0 image is specified, an M4 image, a WLAN image (for QCA4020), then the empty space is reserved on flash to hold a file system.

`gen_fwd_table.py` converts the XML partition_table created by `gen_part_table.py` into another XML file, "fwd_table" (firmware descriptor table), which contains flash directives to be interpreted by tools that handle flash programming.

`QSaharaServer.exe` is used to download the flash programmer over USB from the PC to QCA402x RAM. This tool works only when QCA402x is in Emergency download ("EDL") mode.

`fh_loader.exe` follows directives in the fwd_table XML file. It sends commands and data over USB to the flash programmer that was previously loaded into QCA402x RAM.

The SDK files names "`flash.txt`" in various application directories in the SDK contain detailed instructions to program QCA402x flash.

4.3.11 Flash layout

Firmware consists of multiple image. For example, An M4 image plus an M0 image plus a WLAN image. A set of images that function well together in order to make a QCA402xdevice function is called an ImageSet. It is possible to have more than one ImageSet (each with multiple images) programmed to flash. For example, it is possible to have a "Golden" read-only factory ImageSet plus a "Current" ImageSet, which is the firmware that is loaded and used if the QCA402x device powers on or resets. There might even be a third "Trial" ImageSet which is used during a Firmware Upgrade. If the Trial firmware is determined to be functional, it may be promoted, so that it becomes the "Current" ImageSet.

In addition to firmware, flash may contain one or more file systems. A file system may be tied to a particular ImageSet or may be shared by multiple ImageSets. (This decision is tied to firmware upgrade policies and is related to the size of the ImageSets and size of the flash.) Besides firmware and file systems, flash also contains meta-data known as Firmware Descriptors. The FWDs inform firmware including the Primary Bootloader (PBL) in ROM, about the location of firmware and file systems on flash.

Figure 4-3 shows one possible organization of flash. The firmware and tools are flexible enough to support other organizations but this one is standard.

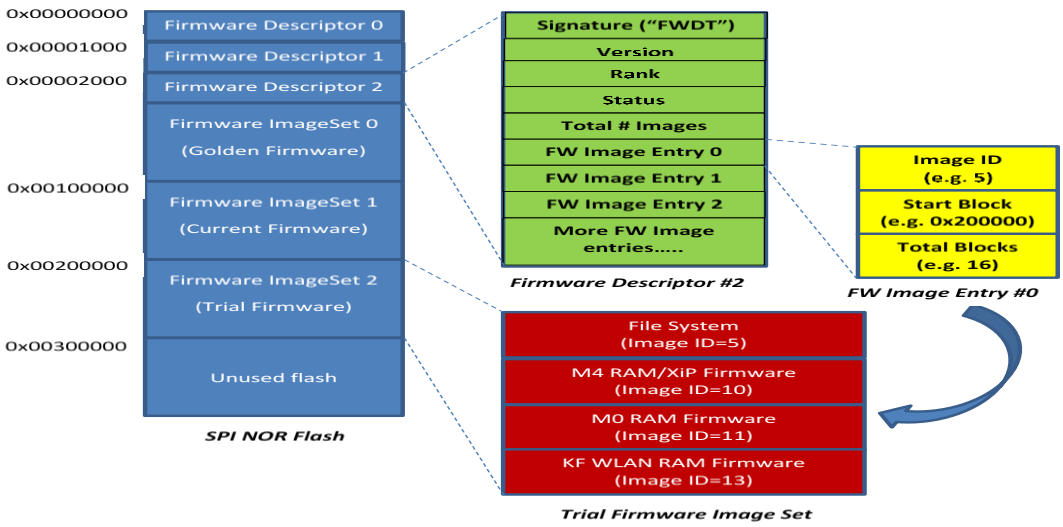


Figure 4-3 QCA402x SPI NOR flash layout

4.3.12 Flash Golden + Current + Trial image set

1. In the **DevCfg_master_fom_out_xxx.xml** file, change "Supported FWD Numbers" to 3 in "fwup_scheme".
2.
```
   <driver name="fwup_scheme">
== snip ==
<props id="0x26001" id_name="FW_UPGRADE_SCHEME_PROP_FWD_SUPPORT_NUM_ID"
oem_configurable="true" helptext="Support FWD Numbers ( 2 - support two
FWDs, 3 - support three FWDs)" type="0x00000002">  3 </props>
```
3. Build the application.
4. Modify the generated_partition_table.xml file in the gcc/output folder

```
      <firmwaredescriptor>
         <instructions erase_block_size_bytes="4096"
      table_align_size_bytes="4096"/>
         <!-- Golden Image -->
         <table>
```

```
      <header rank="0" signature="0x54445746" status="1"
version="1"/>
      <partition
dirname="C:\Build\Quartrz\full_build\3p0_0051_4024_full\ioesw\io
esw\quartz\demo\QCLI_demo\build\gcc\output"
filename="Quartz_HASHED.elf" image_id="10" start_block="35"
size_in_kb="732"/> <!--10-->
      <partition
dirname="C:\Build\Quartrz\full_build\3p0_0051_4024_full\ioesw\io
esw\bin\cortex-m0\threadx" filename="ioe_ram_m0_threadx_ipt.mbn"
image_id="11" size_in_kb="86"/> <!--M0/CONSS Firmware-->
      <partition filename="" image_id="5" start_block="3"
size_in_kb="64"/> <!--Primary Filesystem-->
     <partition filename="" image_id="128" start_block="19"
size_in_kb="64"/> <!--Secondary Filesystem-->
   </table>
   <!-- Current Image  ((732+86) / 4) + Golden_start_block(35)
<= 240 -->
   <table>
      <header rank="1" signature="0x54445746" status="1"
version="1"/>
      <partition
dirname="C:\Build\Quartrz\full_build\3p0_0051_4024_full\ioesw\io
esw\quartz\demo\QCLI_demo\build\gcc\output"
filename="Quartz_HASHED.elf" image_id="10" start_block="240"
size_in_kb="732"/> <!--10-->
      <partition
dirname="C:\Build\Quartrz\full_build\3p0_0051_4024_full\ioesw\io
esw\bin\cortex-m0\threadx" filename="ioe_ram_m0_threadx_ipt.mbn"
image_id="11" size_in_kb="86"/> <!--M0/CONSS Firmware-->
      <partition filename="" image_id="5" start_block="3"
size_in_kb="64"/> <!--Primary Filesystem-->
     <partition filename="" image_id="128" start_block="19"
size_in_kb="64"/> <!--Secondary Filesystem-->
   </table>
</firmwaredescriptor>
```

5. In the gcc folder, run:

   ```
   python ..\..\..\..\..\build\tools\flash\gen_fwd_table.py -x
   output\generated_partition_table.xml --rawprogram
   output\generated_fwd_table.xml --fdtbin output\firmware_table.bin
   ```

6. In gcc folder, run:
   python ..\..\..\..\..\build\tools\flash\qflash.py --nogen --comm xx"

7. After reboot, fwd table shows the updated image set.

8. FWD 0: Golden Image Set
   FWD 1: Current Image Set

9. The trial image can be updated after OTA upgrade. For OTA upgrade, secondary file system (FS2_IMG_ID) is required.

10. FS1_IMG_ID = "5" // 0x5
    M4_IMG_ID = "10" // 0xA
    M0_IMG_ID = "11" // 0xB
    FS2_IMG_ID = "128" // 0x80
    UNUSED_IMG_ID = "129" // 0x81

```
FwUp> fwd

FwUp: Active FWD: Current  index:1, present:3
FwUp: FWD 0
FwUp: Magic: 0x54445746
FwUp: Rank: 0x0
FwUp: Version: 0x1
FwUp: Status: 0x1
FwUp: Total Images: 0x4
FwUp:         Image ID: 0xA
FwUp:    Image Version: 0x0
FwUp:      Image Start: 0x23000
FwUp:       Image Size: 0xB7000
FwUp:         Image ID: 0xB
FwUp:    Image Version: 0x0
FwUp:      Image Start: 0xDA000
FwUp:       Image Size: 0x16000
FwUp:         Image ID: 0x5
FwUp:    Image Version: 0x0
FwUp:      Image Start: 0x3000
FwUp:       Image Size: 0x10000
FwUp:         Image ID: 0x80
FwUp:    Image Version: 0x0
FwUp:      Image Start: 0x13000
FwUp:       Image Size: 0x10000
FwUp:
FwUp: FWD 1
FwUp: Magic: 0x54445746
FwUp: Rank: 0x1
FwUp: Version: 0x1
FwUp: Status: 0x1
FwUp: Total Images: 0x5
FwUp:         Image ID: 0xA
FwUp:    Image Version: 0x0
FwUp:      Image Start: 0xF0000
FwUp:       Image Size: 0xB7000
FwUp:         Image ID: 0xB
FwUp:    Image Version: 0x0
FwUp:      Image Start: 0x1A7000
FwUp:       Image Size: 0x16000
FwUp:         Image ID: 0x5
FwUp:    Image Version: 0x0
FwUp:      Image Start: 0x3000
FwUp:       Image Size: 0x10000
FwUp:         Image ID: 0x80
FwUp:    Image Version: 0x0
FwUp:      Image Start: 0x13000
FwUp:       Image Size: 0x10000
FwUp:         Image ID: 0x81
FwUp:    Image Version: 0x0
FwUp:      Image Start: 0x1000
FwUp:       Image Size: 0x2000
FwUp:
FwUp: FWD 2
FwUp: Magic: 0xFFFFFFFF
FwUp: Rank: 0xFFFFFFFF
FwUp: Version: 0xFFFFFFFF
FwUp: Status: 0xFF
FwUp: Total Images: 0xFF
FwUp:
```

4.3.13 JTAG debug GPIO bootstrap configuration

The debug mode using JTAG depends upon a JTAG debug GPIO bootstrap. This GPIO is kept high during debug which helps the firmware to wait, in a while loop, for JTAG to connect. GPIO20 is used for the JTAG debug mode, by default. If GPIO 20 is used for some other purpose and is kept high, the device goes in to a waiting loop for JTAG and does not boot.

A link time variable 'hold_at_startup_gpio' has been introduced. This variable can be set by the application during linking. SBL uses this variable for getting the GPIO number and uses it for waiting.

To set the GPIO number, the application must change 'hold_at_startup_gpio' to GPIO number in defaultTemplateLinkerScript.ld file:

```
/* Passing the GPIO number for forcing the device to go in to debug loop */
```

```
hold_at_startup_gpio = 20;
```

4.4 Secure boot

For more information on secure boot, refer to *Enable secure boot and Image encryption in the QCA4*02x (CDB2x) document.

4.5 Power measurement

For more information, refer to *QCA402x Power measurement user guide* (80-YA121-146) document.

5 QCA402x debugging tools

The QCA402x SDK contains a tool to log and display debug messages and binary logs.

5.1 Debug script overview

The script to use this tool is `QCA402x_debug.py` and resides at `quartz\tools\qdt`.

This script can log data from a live serial port or can print formatted data from an already collected session file. For each live logging session, this tool creates a session file of type MISF which is used to parse the stored data to user readable text. This filename represents the date and time of logging.

Currently, the tool supports only remote port for collecting DBGLOGs. For more information on how to configure binary logs, refer to Dbglog section in *QCA402x Development Kit User Guide (*80-YA121-140).

Parameters:

```
--session_file :  binary session file (which captured all raw byte stream
from COM port). Session file must be in MISF format.
            OR
--port :  Number for the live serial port.

--out  :  (Optional) output file to store parsed text output. If not
specified STDOUT will be used.

--wlan : (Optional) WLAN dictionary file location with respect to the
directory containing the tool. Default file is
bin/wlan/wlan_fw_dictionary_athwlan_iot.msc
--apps : (Optional) Apps processor dictionary file location with respect to
the directory containing the tool. Default file is bin/cortex-
m4/diag_msg_ARNFRI.strdb
--cnss : (Optional) CNSS processor dictionary file location with respect to
the directory containing the tool. Default file is bin/cortex-
m0/threadx/diag_msg_BRNTRI.strdb
```

Example usage:

```
python QCA402x_debug.py --port=COM57
python QCA402x_debug.py --session_file=09072017_185106.misf --
out="sample.log"
```

5.1.1 Requirements

Follow these steps before running the debug script:

1. **PySerial** package must be installed on the system for using this tool. Refer to https://pypi.python.org/pypi/pyserial/2.7
2. Define DIAG_INIT_COLD from quartz/demo/QCLI_demo/export/platform_oem.h.
3. Diag messages can be collected by one of the two methods as follows:
   a. Debug UART as output drain channel
   b. Edit target/quartz/demo/QCLI_Demo/src/export/DevCfg_master_devcfg_out_cdb.xml and use the following configuration:

```
<driver name="diag">
  <device id="0x02000014">
    <props id="0" type="0x00000008">
    <!-- Last byte is unused placeholder --> 2, 2, 64, 0,
    end
    </props>
    <props id="1" type="0x00000002">256</props>
    <props id="2" type="0x00000002">256</props>
  <props id="3" type="0x00000002">500</props>
  </device>
</driver>
```

   c. USB as output drain channel: This option requires Qualcomm USB Drivers to be downloaded and installed.
   d. Edit target/quartz/demo/QCLI_Demo/src/export/DevCfg_master_devcfg_out_cdb.xml and use the following configuration:

```
<driver name="diag">
  <device id="0x02000014">
    <props id="0" type="0x00000008">
    <!-- Last byte is unused placeholder --> 2, 1, 64, 0,
    end
    </props>
    <props id="1" type="0x00000002">256</props>
    <props id="2" type="0x00000002">256</props>
  <props id="3" type="0x00000002">500</props>
  </device>
</driver>
```

   e. Change the Sleep Driver setting as follows:

```
<driver name="Sleep">
  <global_def>
    <var_seq name="devcfgSleepData" type="0x00000003">
        0, 0, 0,
        180, 166, 200,
        end
```

```
    </var_seq>
  </global_def>
  <device id="0x02000018">
    <props id="0x1" oem_configurable="false" type="0x00000014">
devcfgSleepData </props>
    <props id="0x2" oem_configurable="false" type="0x00000002"> 0
</props>
    <props id="0x3" oem_configurable="false" type="0x00000002"> 632
</props>
    <props id="0x4" oem_configurable="false" type="0x00000002"> 96
</props>
  </device>
</driver>
```

4. Build the application and flash the newly built application. For more information, refer to *QCA402x Development Kit User Guide* (80-YA121-140).
5. The Debug UART must be connected to J85 or USB at J6 on the board.

Example:

```
Log Index Timestamp          Type          Proc  Level  Module          Summary
        1 22:08:04-02282018  DBGLOG        WLAN  LOW    WMI             WMI_AllocEvent: Class:0
        2 22:08:04-02282018  DBGLOG        WLAN  LOW    WMI             WMI_AllocEvent: pool:0 (010)
        3 22:08:04-02282018  DBGLOG        WLAN  LOW    WMI             WMI_AllocEvent: after alloc pool:0 (110)
        4 22:08:04-02282018  DBGLOG        WLAN  LOW    WMI             WMI_SendEvent: EventID: 0x1010 class:0 action:0
        5 22:08:04-02282018  DBGLOG        WLAN  LOW    WMI             WMI_SendEvent: Pending wmi events:1
        6 22:08:06-02282018  DBGLOG        WLAN  LOW    INF             FW: cur_cnt 1 reaped 0
        7 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Send Complete: EventClass:0 (Pending:0)
        8 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Send Complete: calling direct-buffer completion : 0x95FF28
        9 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Free Evt: EventClass:0 (010)
       10 22:08:05-02282018  DBGLOG        WLAN  LOW    INF             Free: 7 HTC: cur_cnt 15 reaped 0
       11 22:08:05-02282018  DBGLOG        WLAN  LOW    INF             MAC: cur_cnt 8 reaped 0
       12 22:08:05-02282018  DBGLOG        WLAN  LOW    INF             FW: cur_cnt 1 reaped 0
       13 22:08:06-02282018  DBGLOG        WLAN  LOW    INF             Free: 7 HTC: cur_cnt 15 reaped 0
       14 22:08:06-02282018  DBGLOG        WLAN  LOW    INF             MAC: cur_cnt 8 reaped 0
       15 22:08:06-02282018  DBGLOG        WLAN  LOW    INF             FW: cur_cnt 1 reaped 0
       16 22:08:05-02282018  DBGLOG        WLAN  LOW    INF             Free: 7 HTC: cur_cnt 15 reaped 0
       17 22:08:05-02282018  DBGLOG        WLAN  LOW    INF             MAC: cur_cnt 8 reaped 0
       18 22:08:05-02282018  DBGLOG        WLAN  LOW    INF             FW: cur_cnt 1 reaped 0
       19 22:08:06-02282018  DBGLOG        WLAN  LOW    INF             Free: 7 HTC: cur_cnt 15 reaped 0
       20 22:08:06-02282018  DBGLOG        WLAN  LOW    INF             MAC: cur_cnt 8 reaped 0
       21 22:08:06-02282018  DBGLOG        WLAN  LOW    INF             FW: cur_cnt 1 reaped 0
       22 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: HTC length:41
       23 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: cmd: 0x000A  length:35
       24 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: dispatching cmd: 0xA  length:35 to 0x9738DC
       25 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS_DUMP_START a 35
       26 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS 1 0
       27 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS 268976920 0
       28 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS 269067432 268977016
       29 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS 0 0
       30 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS 541464 0
       31 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS_DUMP_END
       32 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: done
       33 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: HTC length:14
       34 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: cmd: 0x0009  length:8
       35 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: dispatching cmd: 0x9  length:8 to 0x9738DC
       36 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS_DUMP_START 9 8
       37 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS 268976897 0
       38 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS_DUMP_END
       39 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: done
       40 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: HTC length:26
       41 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: cmd: 0x0007  length:20
       42 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: dispatching cmd: 0x7  length:20 to 0x9738DC
       43 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS_DUMP_START 7 20
       44 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS 0 0
       45 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS 0 1
       46 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS 0 0
       47 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI_CMD_PARAMS_DUMP_END
       48 22:08:06-02282018  DBGLOG        WLAN  LOW    CO              _co_acquire_offchannel_lock(): Priority = 4 Callback : 0x99622c
       49 22:08:06-02282018  DBGLOG        WLAN  LOW    PM              PM Set Beacon Policy 2 1
       50 22:08:06-02282018  DBGLOG        WLAN  LOW    PM              PM Set Beacon Policy 2 1
       51 22:08:06-02282018  DBGLOG        WLAN  LOW    PM              PM Channel Operation Request 1 1
       52 22:08:06-02282018  DBGLOG        WLAN  LOW    WMI             WMI Recv: done
       53 22:08:06-02282018  DBGLOG        WLAN  LOW    PM              PM Set Beacon Policy 1 0
       54 22:08:06-02282018  DBGLOG        WLAN  LOW    PM              PM Set Beacon Policy 1 0
       55 22:08:06-02282018  DBGLOG        WLAN  LOW    PM              PM Channel Operation Request 0 0
       56 22:08:06-02282018  DBGLOG        WLAN  LOW    CO              _co_chanop_event(): Curr SM state=0 Event=1
       57 22:08:06-02282018  DBGLOG        WLAN  LOW    CO              _co_chanop_state_schedule(): Event=0x1 Prev state=0
       58 22:08:06-02282018  DBGLOG        WLAN  LOW    CO              _co_chanop_event(): Scheduler curr SM state =1
       59 22:08:06-02282018  DBGLOG        WLAN  LOW    CO              _co_start_op(): Start time=0x0 Value:0x40100
```

A Configure GPIO functions

This chapter describes the GPIO configuration options supported that the QCA4020/QCA4024 hardware supports.

NOTE: The default configuration for this release is provided in the device configuration file in the SDK package.

Table A-1 QCA402x GPIO function configuration

<table>
<tr><th>Pin name</th><th>Description</th></tr>
<tr><td>GPIO[8]</td><td>
<table>
<tr><td>GPIO configuration</td><td>Interface</td><td>Signal</td></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[8]</td></tr>
<tr><td>1</td><td>UART</td><td>M4_UART0_RX</td></tr>
<tr><td>2</td><td>UART</td><td>M0_UART0_RX</td></tr>
<tr><td>3</td><td>Keypad</td><td>KEY_COL_0_4</td></tr>
<tr><td>4</td><td>Keypad</td><td>KEY_COL_1_3</td></tr>
<tr><td>6</td><td>JTAG</td><td>JTAG1_BE_TCK</td></tr>
</table>
</td></tr>
<tr><td>GPIO[9]</td><td>
<table>
<tr><td>GPIO configuration</td><td>Interface</td><td>Signal</td></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[9]</td></tr>
<tr><td>1</td><td>UART</td><td>M4_UART0_TX</td></tr>
<tr><td>2</td><td>UART</td><td>M0_UART0_TX</td></tr>
<tr><td>3</td><td>Keypad</td><td>KEY_ROW_0_4</td></tr>
<tr><td>4</td><td>Keypad</td><td>KEY_ROW_1_0</td></tr>
<tr><td>6</td><td>JTAG</td><td>JTAG1_BE_TDO</td></tr>
</table>
</td></tr>
<tr><td>GPIO[10]</td><td>
<table>
<tr><td>GPIO configuration</td><td>Interface</td><td>Signal</td></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[10]</td></tr>
<tr><td>1</td><td>I2C master</td><td>I2C0_Master_SCL</td></tr>
<tr><td>3</td><td>Keypad</td><td>Key_col_0_5</td></tr>
<tr><td>4</td><td>Keypad</td><td>Key_row_1_1</td></tr>
<tr><td>6</td><td>JTAG</td><td>JTAG1_BE_TMS</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Pin name</th><th>Description</th></tr>
<tr><td>GPIO[11]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[11]</td></tr>
<tr><td>1</td><td>I2C master</td><td>I2C0_Master_SDA</td></tr>
<tr><td>3</td><td>Keypad</td><td>Key_row_0_5</td></tr>
<tr><td>4</td><td>Keypad</td><td>Key_row_1_2</td></tr>
<tr><td>6</td><td>JTAG</td><td>JTAG1_BE_TDI</td></tr>
</table>
</td></tr>
<tr><td>GPIO[12]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[12]</td></tr>
<tr><td>1</td><td>PWM</td><td>pwm_out_0</td></tr>
<tr><td>2</td><td>Keypad</td><td>key_col_0_6</td></tr>
<tr><td>3</td><td>Keypad</td><td>key_row_1_3</td></tr>
</table>
</td></tr>
<tr><td>GPIO[16]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>1</td><td>UART</td><td>HS_UART0_DM_RFR</td></tr>
<tr><td>2</td><td>I2C master</td><td>I2C1_Master_SCL</td></tr>
<tr><td>3</td><td>SPI</td><td>SPI0_CS2_N</td></tr>
<tr><td>4</td><td>Keypad</td><td>key_row_0_0</td></tr>
<tr><td>5</td><td>Keypad</td><td>key_col_1_7</td></tr>
</table>
</td></tr>
<tr><td>GPIO[17]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>1</td><td>UART</td><td>HS_UART0_DM_RXD</td></tr>
<tr><td>2</td><td>I2C Master</td><td>I2C1_Master_SDA</td></tr>
<tr><td>3</td><td>SPI</td><td>SPI0_CS1_N</td></tr>
<tr><td>4</td><td>Keypad</td><td>key_row_0_1</td></tr>
<tr><td>5</td><td>Keypad</td><td>key_row_1_4</td></tr>
</table>
</td></tr>
<tr><td>GPIO[18]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[18]</td></tr>
<tr><td>1</td><td>PWM</td><td>pwm_out_6</td></tr>
<tr><td>2</td><td>SDIO/SPI</td><td>SDIO_Slave_CLK/
SPI_Slave_CLK</td></tr>
<tr><td>3</td><td>SDCC</td><td>SD_Master_CLK (O)</td></tr>
<tr><td>5</td><td>UART</td><td>HS_UART1_DM_CTS</td></tr>
<tr><td>6</td><td>Keypad</td><td>key_row_1_5</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Pin name</th><th>Description</th></tr>
<tr><td>GPIO[19]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[19]</td></tr>
<tr><td>1</td><td>PWM</td><td>pwm_out_1</td></tr>
<tr><td>2</td><td>SDIO/SPI</td><td>SDIO_Slave_CMD/
SPI_Slave_CS_N</td></tr>
<tr><td>3</td><td>SDCC</td><td>SD_Master_CMD (B)</td></tr>
<tr><td>5</td><td>UART</td><td>HS_UART1_DM_TXD</td></tr>
<tr><td>6</td><td>Keypad</td><td>key_col_0_3</td></tr>
<tr><td>7</td><td>Keypad</td><td>key_row_1_6</td></tr>
</table>
</td></tr>
<tr><td>GPIO[20]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[20]</td></tr>
<tr><td>1</td><td>PWM</td><td>pwm_out_2</td></tr>
<tr><td>2</td><td>SDIO</td><td>SDIO_Slave_DATA_0/
SPI_SLAVE_MISO</td></tr>
<tr><td>3</td><td>SDCC</td><td>SD_Master_DATA_0 (B)</td></tr>
<tr><td>4</td><td>UART</td><td>HS_UART1_DM_RXD</td></tr>
<tr><td>5</td><td>Keypad</td><td>key_row_0_2</td></tr>
<tr><td>6</td><td>Keypad</td><td>key_row_1_7</td></tr>
</table>
</td></tr>
<tr><td>GPIO[21]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[21]</td></tr>
<tr><td>1</td><td>PWM</td><td>pwm_out_4</td></tr>
<tr><td>2</td><td>SDIO</td><td>SDIO_Slave_DATA_1</td></tr>
<tr><td>3</td><td>SDCC</td><td>SD_Master_DATA_1 (B)</td></tr>
<tr><td>4</td><td>Keypad</td><td>key_row_0_3</td></tr>
</table>
</td></tr>
<tr><td>GPIO[22]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[22]</td></tr>
<tr><td>1</td><td>PWM</td><td>pwm_out_3</td></tr>
<tr><td>2</td><td>SDIO</td><td>SDIO_Slave_DATA_2</td></tr>
<tr><td>3</td><td>SDCC</td><td>SD_Master_DATA_2 (B)</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Pin name</th><th>Description</th></tr>
<tr><td>GPIO[23]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[23]</td></tr>
<tr><td>1</td><td>PWM</td><td>pwm_out_5</td></tr>
<tr><td>2</td><td>SDIO</td><td>SDIO_Slave_DATA_3/
SPI_SLAVE_MOSI</td></tr>
<tr><td>3</td><td>SDCC</td><td>SD_Master_DATA_3 (B)</td></tr>
<tr><td>5</td><td>UART</td><td>HS_UART1_DM_RFR</td></tr>
</table>
</td></tr>
<tr><td>GPIO[24]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[24]</td></tr>
<tr><td>1</td><td>SPI</td><td>SPI0_Master_CS_N</td></tr>
<tr><td>2</td><td>UART</td><td>M0_UART2_RX</td></tr>
<tr><td>3</td><td>UART</td><td>M4_UART2_RX</td></tr>
<tr><td>4</td><td>Keypad</td><td>key_col_0_7</td></tr>
<tr><td>7</td><td>JTAG</td><td>JTAG2_BE_TCK</td></tr>
</table>
</td></tr>
<tr><td>GPIO[25]</td><td>
<table>
<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[25]</td></tr>
<tr><td>1</td><td>SPI</td><td>SPI0_Master_CLK</td></tr>
<tr><td>2</td><td>UART</td><td>M0_UART2_TX</td></tr>
<tr><td>3</td><td>UART</td><td>M4_UART2_TX</td></tr>
<tr><td>4</td><td>Keypad</td><td>key_row_0_7</td></tr>
<tr><td>7</td><td>JTAG</td><td>JTAG2_BE_TDO</td></tr>
</table>
</td></tr>
<tr><td>GPIO[26]</td><td>
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<tr><th>GPIO configuration</th><th>Interface</th><th>Signal</th></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[26]</td></tr>
<tr><td>1</td><td>SPI</td><td>SPI0_Master_MOSI</td></tr>
<tr><td>2</td><td>Keypad</td><td>key_col_0_2</td></tr>
<tr><td>6</td><td>JTAG</td><td>JTAG2_BE_TMS</td></tr>
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<tr><td>GPIO[27]</td><td>
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<tr><td>1</td><td>SPI</td><td>SPI0_Master_MISO</td></tr>
<tr><td>5</td><td>JTAG</td><td>JTAG2_BE_TDI</td></tr>
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<tr><td>GPIO[42]</td><td>
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<tr><td>0</td><td>GPIO</td><td>GPIO[42]</td></tr>
<tr><td>1</td><td>QUAD SPI master</td><td>QSPI_Master_CLK</td></tr>
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<table>
<tr><th>Pin name</th><th>Description</th></tr>
<tr><td>GPIO[43]</td><td>
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<tr><td>0</td><td>GPIO</td><td>GPIO[43]</td></tr>
<tr><td>1</td><td>QUAD SPI master</td><td>QSPI_Master_DAT0</td></tr>
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</td></tr>
<tr><td>GPIO[44]</td><td>
<table>
<tr><td>GPIO configuration</td><td>Interface</td><td>Signal</td></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[44]</td></tr>
<tr><td>1</td><td>QUAD SPI master</td><td>QSPI_Master_DAT1</td></tr>
</table>
</td></tr>
<tr><td>GPIO[45]</td><td>
<table>
<tr><td>GPIO configuration</td><td>Interface</td><td>Signal</td></tr>
<tr><td>0</td><td>GPIO</td><td>GPIO[45]</td></tr>
<tr><td>1</td><td>QUAD SPI master</td><td>QSPI_Master_DAT2</td></tr>
</table>
</td></tr>
<tr><td>GPIO[46]</td><td>
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Pin name	Description
GPIO[59]	GPIO configuration: 0 — Interface: GPIO — Signal: GPIO[59] GPIO configuration: 2 — Interface: UART — Signal: HS_UART2_DM_CTS (I)
GPIO[60]	GPIO configuration: 0 — Interface: GPIO — Signal: GPIO[60] GPIO configuration: 4 — Interface: UART — Signal: HS_UART2_DM_TXD (O)

Table A-2 QCA4020 GPIO function configuration

Pin name	Description
GPIO[4]	GPIO configuration: 1 — Interface: GPIO — Signal: WL_WKUP_BE
GPIO[5]	GPIO configuration: 1 — Interface: GPIO — Signal: BT_ACTIVE GPIO configuration: 4 — Interface: Keypad — Signal: KEY_COL_1_0
GPIO[6]	GPIO configuration: 1 — Interface: GPIO — Signal: WLAN_ACTIVE GPIO configuration: 4 — Interface: Keypad — Signal: KEY_COL_1_1
GPIO[7]	GPIO configuration: 1 — Interface: GPIO — Signal: BT_PRIORITY GPIO configuration: 2 — Interface: Keypad — Signal: KEY_COL_1_2
GPIO[13]	GPIO configuration: 0 — Interface: GPIO — Signal: GPIO[13] GPIO configuration: 1 — Interface: PWM — Signal: pwm_out_7 GPIO configuration: 3 — Interface: Keypad — Signal: key_row_0_6 GPIO configuration: 4 — Interface: Keypad — Signal: key_col_1_4

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<tr><td>1</td><td>UART</td><td>HS_UART0_DM_CTS</td></tr>
<tr><td>2</td><td>Keypad</td><td>key_col_0_0</td></tr>
<tr><td>3</td><td>Keypad</td><td>key_col_1_5</td></tr>
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<tr><td>1</td><td>UART</td><td>HS_UART0_DM_TXD</td></tr>
<tr><td>2</td><td>Keypad</td><td>Key_col_0_1</td></tr>
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