**Abstract**

This application note discusses how to connect i.MX RT1060 EVK to Internet by USB 4G module like EC200A-CN from Quectel.

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1 Introduction

There is one SDK example `evkbimxrt1060_lwip_dhcp_usb_bm` in the i.MX RT1060 EVK SDK. It connects the USB to the Internet with the three cell phones mentioned in the guide. But if customer wants to use a USB 4G module, instead of a cell phone listed in the guide, to connect to the Internet, and it is possible that this example cannot work in such condition. Then we must adapt this example to new USB 4G module.

This application note discusses how to implement the adaption when the terminal becomes a USB 4G module like EC200A-CN from Quectel, and then connect to the Internet with this USB 4G module.

2 Basics

2.1 Introduction of RNDIS

Remote Network Driver Interface Specification (RNDIS) is a USB protocol defined by Microsoft. The windows OS can recognize the USB device which follows this specification automatically and treat it as a network device, as shown in Figure 1.

![Figure 1. USB 4G module connected to windows](image)

2.2 Network layer model for USB RNDIS

Figure 2 shows the network layer model for USB RNDIS.

![Figure 2. Network layer model for USB RNDIS](image)

2.3 RNDIS interface/endpoint analysis

In the original SDK example, it uses two interfaces and three endpoints.
Here, the data interface is used for Ethernet package communication, and there is one endpoint for each direction. RNDIS interface is used for device status polling.

2.4 EC200A-CN interface/endpoint analysis

EC200A-CN implements five interfaces, which include the interfaces introduced above.

The additional interface used here is the AT interface.
The AT interface is used to dial (send AT command and get response), poll, and control the USB 4G module. We need poll the USB 4G module status and send the command to it to set it to the online mode. Then, the IP package from/to RT1060 EVK can be sent to/received from the Internet.

To enable/adapt to the new 4G module, we must:

- Enable AT interface
- Dial on AT interface

The other interfaces defined by the EC200A-CN are not important for us here, so they are not introduced in this document.

### 2.5 Some basics for USB host application by NXP SDK

- NXP SDK USB stack decodes the configuration descriptor automatically. It can detect all the interfaces and endpoints in the configuration descriptor.
  
  See `USB_HostParseDeviceConfigurationDescriptor()` in `usb/host/usb_host_devices.c`. 
  
  Figure 6 shows the related call stack. Call stack analysis is useful for us to understand how the SDK USB stack is organized.

- For the event callback, see `USB_HostEvent()` in `lwip/port/usb_ethernetif_bm.c`. Figure 7 shows the related call stack.
• Open pipe for each interface.
  See `USB_HostCdcOpenDataInterface()` and `USB_HostCdcOpenControlInterface()` in `usb_host_cdc.c`.
  Figure 8 shows the related call stack.

  ```
  USB_HostOpenPipe() at usb_host_hd.c:356 0x60019e4a
  USB_HostCdcOpenDataInterface() at usb_host_cdc.c:339 0x6002836
  USB_HostCdcSetDataInterface() at usb_host_cdc.c:338 0x60002d36
  USB_HostCdcRndisTask() at usb_ethernetif_bm.c:344 0x60013940
  USB_HostApplicationInit() at usb_ethernetif_bm.c:351 0x6001304a
  USB_EthernetIfInit() at usb_ethernetif_bm.c:382 0x600130ca
  netif_4addr() at netif.c:388 0x6000c504
  main() at lwip_dhcp_usb_bm.c:279 0x60006da4
  ```

  Figure 8. Call stack for `USB_HostCdcOpenDataInterface()`

• State machine maintenance
  For state machine maintenance, refer to `USB_HostCdcRndisTask()` and `USB_HostCdcRndisControlCallback()` in `lwip/port/usb_ethernetif_bm.c`.
  Figure 9 shows the default state machine. Adjust it to enable the AT interface and dial on AT interface.

```
RunIdle
  └── SetControlInterface
      └── SetControlInterfaceDone
          └── SetDataInterfaceDone
              └── WaitInitMsgDone
                  └── WaitMaxFrameDone

GetMACAddress
  └── GetMACAddressDone
      └── SetMsg
          └── SetMsgDone
              └── GetState
                  └── DataReceive
```

Figure 9. State machine maintenance
3 Details for implementation

Based on the introduction above, this section discusses the implementation details. Some code is presented here. For more details, see AN13940SW.

The main code changes are in:

- `usb_ethernet_bm.c`
- `usb_ethernet.h`

Some key code changes include:

- Add the data structure for AT interface. It is in `sdk_root/lwip/port/usb_ethernetif.h`.

```c
typedef struct _usb_host_rndis_instance_struct
{
    usb_device_handle deviceHandle;
    usb_host_class_handle classHandle;
    usb_host_interface_handle controlInterfaceHandle;
    usb_host_interface_handle dataInterfaceHandle;
    usb_host_class_handle classHandle_at;
    usb_host_interface_handle dataInterfaceHandle_at;
} _usb_host_rndis_instance;
```

Figure 10. Add the data structure for AT interface

- Add class initial code in attach event. It is in `lwip/port/usb_ethernetif_bm.c`.

```c
case kStatus_DEV_Attached:
    rndisInstance->runState = kUSB_HostCdcRndisRunSetControlInterface;
    status = USB_HostCdcInit(rndisInstance->deviceHandle, &rndisInstance->classHandle);
    if(status == kStatus_USB_Success)
    {
        usb_echo("init cdc classHandle done. \n\n");
    }
}
```

```c
status = USB_HostCdcInit(rndisInstance->deviceHandle, &rndisInstance->classHandle_at);
if(status == kStatus_USB_Success)
{
    usb_echo("init cdc classHandle_at done. \n\n");
}
```

Figure 11. Add class initial code

- Add de-init code in de-attach event. It is in `lwip/port/usb_ethernetif_bm.c`.
• Update the state machine `enum` variable.
  It is in `lwip/port/usb_ethernetif.h`.

```c
typedef enum HostCdcRndisRunState {
    kUSB_HostCdcRndisRunIdle = 0,
    kUSB_HostCdcRndisRunSetControlInterface,
    kUSB_HostCdcRndisRunSetDataInterface,
    kUSB_HostCdcRndisRunSetMaxFrame,
    kUSB_HostCdcRndisRunEC280AInit,
    kUSB_HostCdcRndisRunEC280AInitDone,
    kUSB_HostCdcRndisRunEC280ADoneInit,
    kUSB_HostCdcRndisRunEC280ADoneInitDone,
    kUSB_HostCdcRndisRunEC280ADone,
    kUSB_HostCdcRndisRunEC280ADoneDone,
    kUSB_HostCdcRndisRunUDAL,
    kUSB_HostCdcRndisRunUDALDone,
} kUSB_HostCdcRunState;
```

Figure 13. Update state machine

• Update state machine implementation function.
  It is in `lwip/port/usb_ethernetif_bm.c`.

Figure 12. Add de-init code in de-attach event
Connect i.MX RT1060 to USB 4G Module (RNDIS Mode)

Figure 14. Update state machine implementation function

```c
case kUSB_HostCdcRndisRunSetDataInterfaceDone:
    rndisInstance->runWaitState = kUSB_HostCdcRndisRunWaitSetATDataInterface;
    rndisInstance->runState = kUSB_HostCdcRndisRunIdle;
    if (USB_HostCdcSetDataInterface(rndisInstance->classHandle_at, 
                                rndisInstance->dataInterfaceHandle_at, 
                                0, 
                                USB_HostCdcRndisControlCallback, 
                                rndisInstance) != kStatus_USB_Success)
    {
        usb_echo("set at interface error\r\n");
    }

    break;
```

- Add related API and callback. The function parameter is not displayed here. For more details, see AN13940SW.

```c
USB_HostCdcRndisATInCallback();
USB_HostCdcRndisATOutCallback();
dial_tx(); // Send command on AT interface
dial_rx(); // Receive message from AT interface
lte_dial(); // Dial, then USB 4G module can connect to internet
USB_HostCdcRndisEC200ACallback();
ep0_communicate(); // API used for AT interface enablement, to send/receive command/message to/from EP0
init_ec200a(); // Initiate EC200A, then AT interface communication is available
```

- The maximum interfaces number is supported. The maximum interfaces number is different when connected to different USB 4G module. The update is required. For example, if using the LE910C1-EU, update the value to 8.

```c
#define USB_HOST_CONFIG_CONFIGURATION_MAX_INTERFACE (8U)
```

- Implement the new state machine for AT interface enablement and dial on AT interface. The main code change is in function USB_HostCdcRndisControlCallback() and USB_HostCdcRndisTask() in lwip/portusb_ethernetif_bm.c. For more details, see AN13940SW.

- Adapt AT interface. The AT data interface index is decoded from USB analyzer when connecting the USB 4G module to a PC. The code is from USB_HostCdcRndisEvent() in lwip/portusb_ethernetif_bm.c, it assigns interfaceList[3] to the g_RndisInstance, dataInterfaceHandle_at, and implements the binding.
Figure 16. Bind AT interface
Run the code after all code changes, and we can see that the i.MX RT1060 EVK is connected to the Internet successfully with USB 4G module EC200A-CN.

```c
// at interface.
hostInterface = &configuration->interfacelist[3];
g_RndisInstance.dataInterfaceHandle_at = hostInterface;

g_RndisInstance.deviceHandle = deviceHandle;
if ((NULL != g_RndisInstance.dataInterfaceHandle) &&
    (NULL != g_RndisInstance.controlInterfaceHandle) &&
    (NULL != g_RndisInstance.dataInterfaceHandle_at))
{
    status = kStatus_USB_Success;
}
else
{
    usb_echo("= 0001 \r\n");
    status = kStatus_USB_NotSupported;
}
break;
```
4 Attention

Make sure that the power supply is enough for USB 4G module. In this case, the i.MX RT1060 EVK is powered with an external power adapter, instead of with a USB cable. Otherwise, the USB 4G module resets when it tries to enable the RF to connect to the Internet.
5 Conclusion

This application note discusses the basic knowledge and details about how to connect i.MX RT1060 EVK to the Internet by USB 4G module EC200A-CN. It can be helpful for user reference when they want to connect to the Internet with the same or other USB 4G modules.
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