
Serialized G3-PLC Coordinator on Linux[®]

Summary

This application note implements an example of G3-PLC Coordinator making use of Microchip `usi_host` package on top of a device running as G3-PLC Modem. The example project is based on a Linux process running on a SAMA5D27-SOM1-EK board connected through a serial port to a PL360G55CF-EK board running the G3-PLC Modem. The final application schema is similar to the embedded G3-PLC DLMS Coordinator project except for the fact that DLMS cycling is not implemented on the current application.

Figure 1. Serialized G3-PLC Coordinator scheme

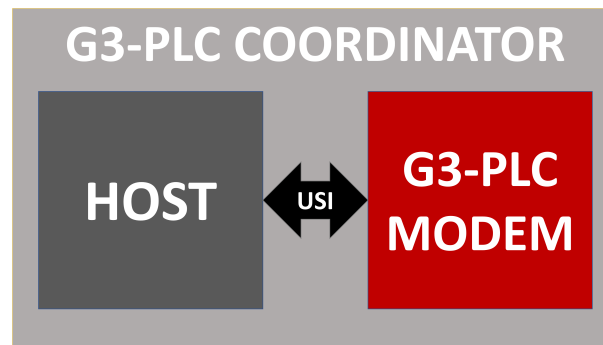


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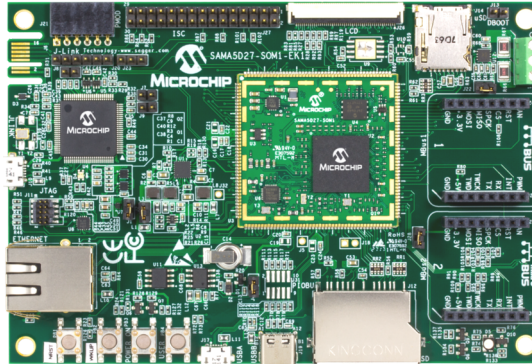
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1. Hardware Description

The project is based on these evaluation boards:

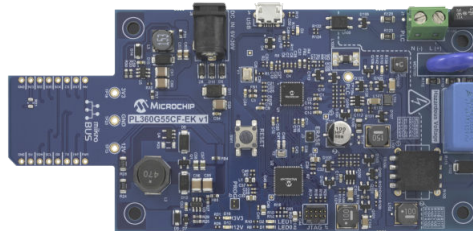
- SAMA5D27-SOM1-EK1
 - <https://www.microchip.com/developmenttools/ProductDetails/atsama5d27-som1-ek1>

Figure 1-1. SAMA5D27-SOM1-EK1



- PL360G55CF-EK
 - <https://www.microchip.com/developmenttools/ProductDetails/pl360g55cf-ek1>

Figure 1-2. PL360G55-CF EK



Both boards are already available as evaluation kits from Microchipdirect.com and distributors, containing software, hardware schematics, Bill of Materials and PCB designs.

SAMA5D27-SOM1-EK includes two mikroBUS™ connectors where PL360G55CF-EK could be connected. MikroBUS 1 is used by default. Figure 1-3 and Figure 1-4 show the mikroBUS schematic on both evaluation kits.

Figure 1-3. SAMA5D27-SOM1-EK1 mikroBUS 1

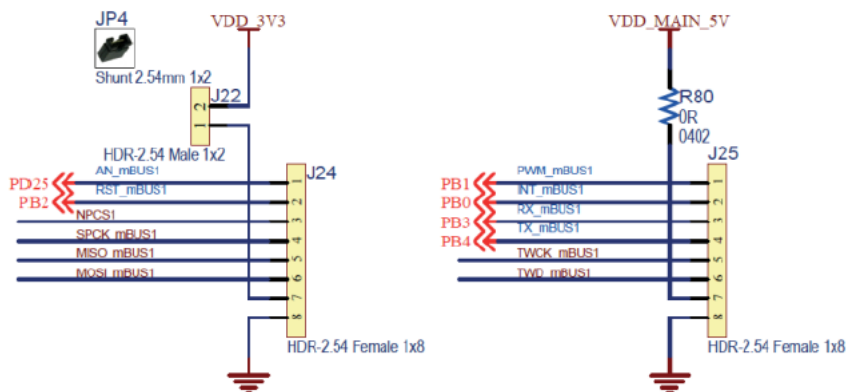
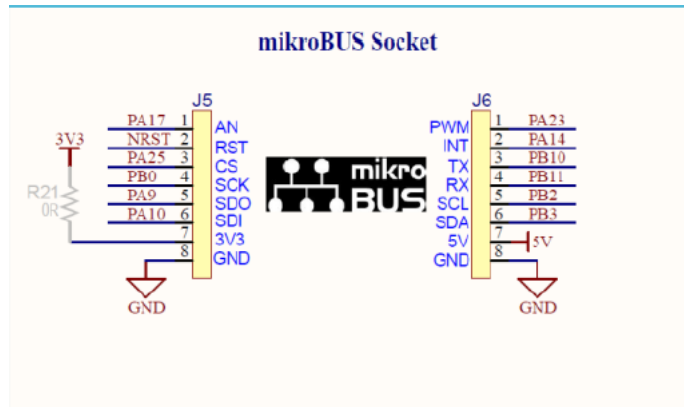


Figure 1-4. PL360G55-CF EK mikroBUS



SAMA5D27-SOM1-EK1 is powered by USB and PL360G55CF-EK is powered by 5V pin in mikroBUS™. As the project is using mikroBUS 1 of SAMA5D27-SOM1-EK1, please, verify in the SAMA5D27-SOM1-EK1 board that the resistor R80 is soldered in order to enable the 5 Volts pin to supply power (in case of using mikroBUS 2, the resistor to check is R109) .

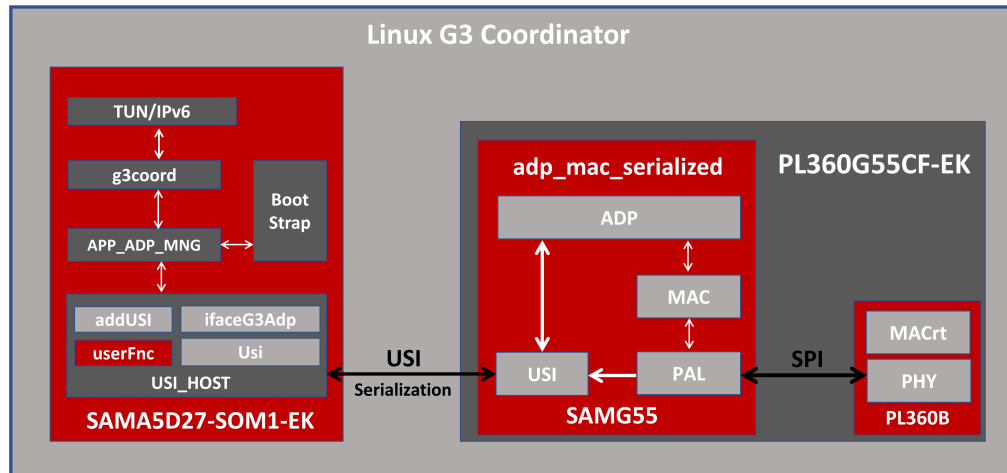
A SD card is also required to run the Linux™ image of the project. The SD card is connected in the SD connector of SAM5D27-SOM1-EK1 (J12)

2. Software Description

This walkthrough will allow users to build, on a Linux environment, a G3-PLC Linux Coordinator example with bootstrapping capabilities running on a SAMA5D27 microprocessor. The PL360G55CF-EK runs the application example “adp_mac_serialized” included in the Microchip G3-PLC stack release and the communication interface between both boards is handled by **usi_host** package.

Figure 2-1 shows the software and hardware relationships between the different elements.

Figure 2-1. Linux G3-PLC Coordinator Software Blocks



2.1 PL360G55CF-EK Embedded Project

PL360G55CF-EK is flashed with a modified version of the project `adp_mac_serialized` from the Firmware package G3_v1.4.0. The original project is the following path of the G3-PLC stack package:

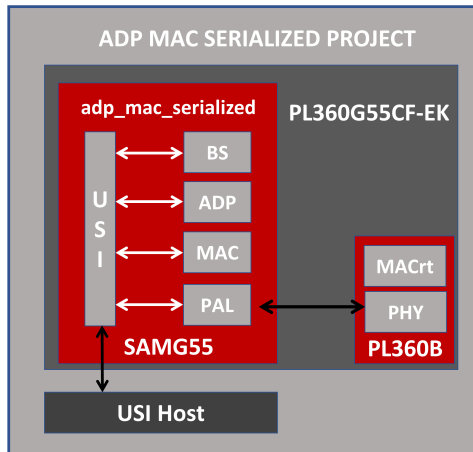
```
\thirdparty\g3\apps\adp_mac_serialized_app\samg55j19_pl360g55cf_ek
```

The ADP and MAC serialization is an application example that brings access to the ADP, MAC and Coordinator API through a serial connection. This application is useful for users who want to make intensive test of the stack or want to run the upper layers in another CPU.

The application allows to control the G3-PLC Stack at different levels. The user can make use of the ADP API (standard access) or access MAC Wrapper API directly as a shortcut for some tests. Serialization is also available to the provided Coordinator module (BS) in case the user requires to control the Bootstrap phase on the Coordinator side. On the modification of the example used in this application note, the access to the stack will be done at ADP-MAC layers and the Coordinator module will be implemented on the host.

The Figure 2-2 shows the `adp_mac_serialized` project structure on PL360G55CF-EK, where PL360B PLC transceiver runs the G3-PLC MAC real time firmware in order to reduce timing restrictions on the SAMG55 MCU:

Figure 2-2. ADP MAC Serialized Project Stack



By default, in the `adp_max_serialized` project, the USI port is the USB of the PL360G55CF-EK board. In our case, mikroBUS UART is used, which requires some modifications in two header files.

In the header file `conf_usi.h`, to use mikroBUS UART and serialize PHY layer to use the sniffer capabilities in the example:

```
#ifndef CONF_USI_H_INCLUDED
#define CONF_USI_H_INCLUDED

#define USI_PORT_0      0

/* Port Communications configuration */
#define NUM_PORTS      1
/* In case of use USB_TYPE, refer to conf_usb.h in order to set baudrate by default */
/* #define PORT_0 CONF_PORT(USB_TYPE, 0, 230400, 1024, 1024) */
/* In case of USI on Mikro BUS, comment previous line, and uncomment next line and
conf_busart_if.h configurations */
#define PORT_0 CONF_PORT(USART_TYPE, 0, 230400, 2048, 2048)

/* Select PORT to serialize layers */
#define ADP_SERIAL_PORT      USI_PORT_0
#define MAC_SERIAL_PORT      USI_PORT_0
#define COORD_SERIAL_PORT    USI_PORT_0
#define PHY_SNIFFER_SERIAL_PORT  USI_PORT_0

#endif /* CONF_USI_H_INCLUDED */
```

In the header file `conf_busart_if.h`, to use USI port on the mikroBUS UART:

```
#ifndef CONF_BUSART_IF_H_INCLUDED
#define CONF_BUSART_IF_H_INCLUDED

/* Uncomment if USI port on mikro BUS */

#define ID_TC_USART      ID_TC4
#define TC_USART        TC1
#define TC_USART_CHN    1
#define TC_USART_Handler  TC4_Handler

#define BUSART0          USART4
#define ID_BUSART0      ID_FLEXCOM4
#define BUSART0_IRQn    FLEXCOM4_IRQn
#define BUSART0_Handler  FLEXCOM4_Handler
#define RX_BUSART0_SIZE  2048
#define TX_BUSART0_SIZE  2048

#endif /* CONF_BUSART_IF_H_INCLUDED */
```

2.2 Setting up the Linux Environment

The Linux binaries that run in ATSAM5D27-SOM1 are generated using Buildroot (<https://buildroot.org/>), a tool to generate embedded Linux systems through cross-compilation. Microchip provides its own version of Buildroot which includes kernel, cross compiler and rootfs for ATSAM5D27-SOM1 Evaluation Kit. More information can be found at:

- http://www.at91.com/linux4sam/bin/view/Linux4SAM/BuildRootBuild#How_to_build_Buildroot_for_AT91
- <https://www.at91.com/linux4sam/bin/view/Linux4SAM/Sama5d27Som1EKMainPage>
- ftp://www.at91.com/pub/demo/linux4sam_5.8/

To describe the building procedure of an SD image with the Linux binaries, we are using a PC running Ubuntu 19.10. In case of using a different version or distribution, the process may vary.

1. Install some packages not included in the Linux distribution (for more information about the system requirements, see <http://buildroot.uclibc.org/downloads/manual/manual.html#requirement>):

```
$ sudo apt-get install sed make binutils build-essential gcc g++ bash patch
$ sudo apt-get install gzip bzip2 perl tar cpio python unzip rsync file bc wget
$ sudo apt-get install libncurses5-dev libncursesw5-dev bzip2 cvs git mercurial rsync
$ sudo apt-get install subversion graphviz python-matplotlib
```

2. Download the sources of Microchip Buildroot (at this moment, the last released version is 6.2)

```
$ git clone https://github.com/linux4sam/buildroot-at91.git
$ git clone https://github.com/linux4sam/buildroot-external-microchip.git
$ git checkout tags/linux4sam_6.2 -b buildroot-at91-linux4sam_6.2
$ git checkout tags/linux4sam_6.2 -b buildroot-ext-mchp_linux4sam_6.2
```

3. Build the Microchip Buildroot rootfs image

```
$ cd buildroot-at91
$ BR2_EXTERNAL=../buildroot-external-microchip/ make sama5d27_som1_ek_headless_defconfig
$ make
```

4. Customize the buildroot and save the configuration:

```
$make menuconfig
```

Enable the following configurations/packages

- \Target Packages\Networking applications\iputils (**BR2_PACKAGE_IPUTILS=y**)
- \Target Packages\Networking applications\openssh (**BR2_PACKAGE_OPENSSSH=y**)

To run the example bash file of the application note:

- \Target Packages\Shell and utilities\inotify-tools (**BR2_PACKAGE_INOTIFY_TOOLS=y**)

5. Run the Buildroot compilation:

```
$make
```

Buildroot downloads and compile all the packages required, so it may take quite a long time. After this point, the kernel, cross-compiler and rootfs are ready to flash your system.

6. G3-PLC Coordinator requires TUN/TAP interfaces which must be part of the kernel, otherwise, the example will not work. To enable TUN/TAP interface in the kernel configuration:

```
$make linux-menuconfig
```

Enable the TUN/TAP support as a module:

- \Device Drivers\Network Device Support\Universal TUN/TAP device driver support"

```
$make linux-build
```

7. Create the SD image:

```
$make
```

8. After compiling all the binaries needed, update SD card image to be mounted on SAMA5D27-SOM1-EK with the correct binaries located in:

```
buildroot-at91/output/images/sdcard.img
```

The Linux binaries are ready to be used, follow these steps to verify proper operation of the kit:

1. Insert the SD card is the MMC/SD card connector (J12)
2. Connect the USB Micro-AB cable to connector J10 (JLINK-OB)
3. Connect the other end of the cable to a free port of your PC
4. Open a terminal (console 115200, N, 8, 1) on your Personal Computer
5. Reset the baseboard. A start-up message appears on the console.

In order to use the Ethernet connector and access easily to SAMA5D27-SOM1-EK1, configure a new IP address:

```
$ ip address add 192.168.1.102/24 dev eth0
$ ifconfig eth0 up
```

So, in this case, <target-ip-address> is 192.168.1.102

3. Features of Microchip G3-PLC Linux Coordinator Application

The example developed in this application note uses the package `usi-host-v2.0.0`, but it requires some modifications. To start working on it, extract the contents of the package `010-usi-host-g3coord_linux.7z`.

Figure 3-1. Linux G3-PLC Coordinator Structure

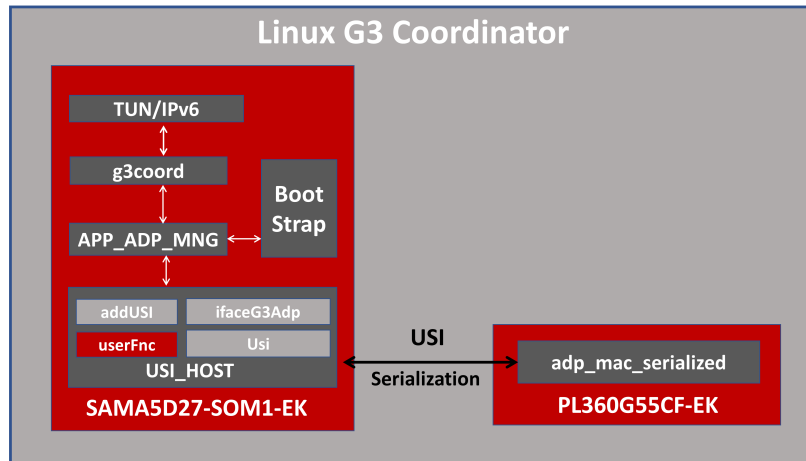


Figure 3-1 shows the structure of the G3-PLC coordinator daemon developed on this example.

Working with `usi_host` serialization requires the following points:

- USI Project Configuration (`PrjCfg.h` file): definitions required to enable `PROTOCOL_ADP_G3` and serial port configuration to `ttyS1` with speed 230400bps (mikroBUS-1 serial port propagated by Linux; in case of the mikroBUS-2 connection, `ttyS2` should be used).
- USI user functions (`userFnc.c` file): Implement the functions `addUsi_Open()`, `addUsi_TxMsg()` and `addUsi_RxChar()` required for the USI implementation.
- Call USI host processing periodically (`addUsi_Process()` function). In this example an independent thread in the Linux operating system calls `usi_process_thread()` every 1 millisecond.
- Synchronous mechanism implementation for ADP/MAC Set/Get requests defining `addUsi_WaitProcessing()` function with a "while loop" with timeout. This is not a problem working in Linux running a multi process environment.

The `ifaceG3Adp.c` file includes the interface between `adp_mac_serialized` embedded project and the application; it contains the functions and callbacks available for the USI protocol `PROTOCOL_ADP_G3`. In the other hand, the bootstrapping (BS) part of G3-PLC coordinator application is not handled by the USI protocol `PROTOCOL_COORD_G3` (available on `adp_mac_serialized` embedded project); but it is included in folder "g3\bootstrap", in this way, Linux `g3coord` application has more control of the status of the G3-PLC devices on the network reducing the overhead to request this information via USI.

The ADP and bootstrapping management applications are developed on `app_adp_mng.c` file:

- `adp_init()`:
 - `InitializeStack()`: Sets ADP notification callbacks and initializes the ADP layer
 - `InitializeModemParameters()`: Sets ADP and MAC PIB attributes specific for the application
 - `InitializeNetworkParameters()`: Sets IPv6 Prefix Table Entry: Coordinator IPv6Addr
- `adp_process()`:
 - `StartCoordinator()`: Initialize BS module, sets BS callbacks for events and starts the G3 Network
 - `bs_process()`: Update status of BS module
- Boot Strapping (bs folder): implemented on Linux in order to have more control of the G3-PLC device registering process

Additional features implemented at application layer:

- tun/ipv6: a TUN interface is created in order to provide IPv6 access to the G3-PLC Network (`tun.c`)
- IPv6 Local Link addresses of joined devices are propagated to the defined temporary file `G3_PLC_NODE_LIST` (via ADP callback `AppBsJoinIndication()`) for user application
- G3-PLC Buffer overflow is propagated to the defined temporary file `ADP_DATA_BLOCKING_FILE` (via ADP callback `AppAdpBufferIndication()`). It could be used for flow control on applications over IP Layer
- Use of Linux SYS Filesystem to act over microprocessor GPIOs (`gpio.c`) and LEDs (`led.c`)

3.1 Building Microchip G3-PLC Linux Coordinator Application

1. The G3-PLC Linux Coordinator example is developed starting from `usi_host` package 2.0.0

```
$ cd ~/010-usi-host/g3coord_linux
```

2. Select cross-compiler configuring the environment variable `CROSS_COMPILE`

```
$ export CROSS_COMPILE=~/.linux_coord/buildroot-at91/output/host/bin/arm-buildroot-linux-gnueabihf-
```

3. Clean and compile the code:

```
$ make clean && make all
```

4. Copy the compiled application to the target

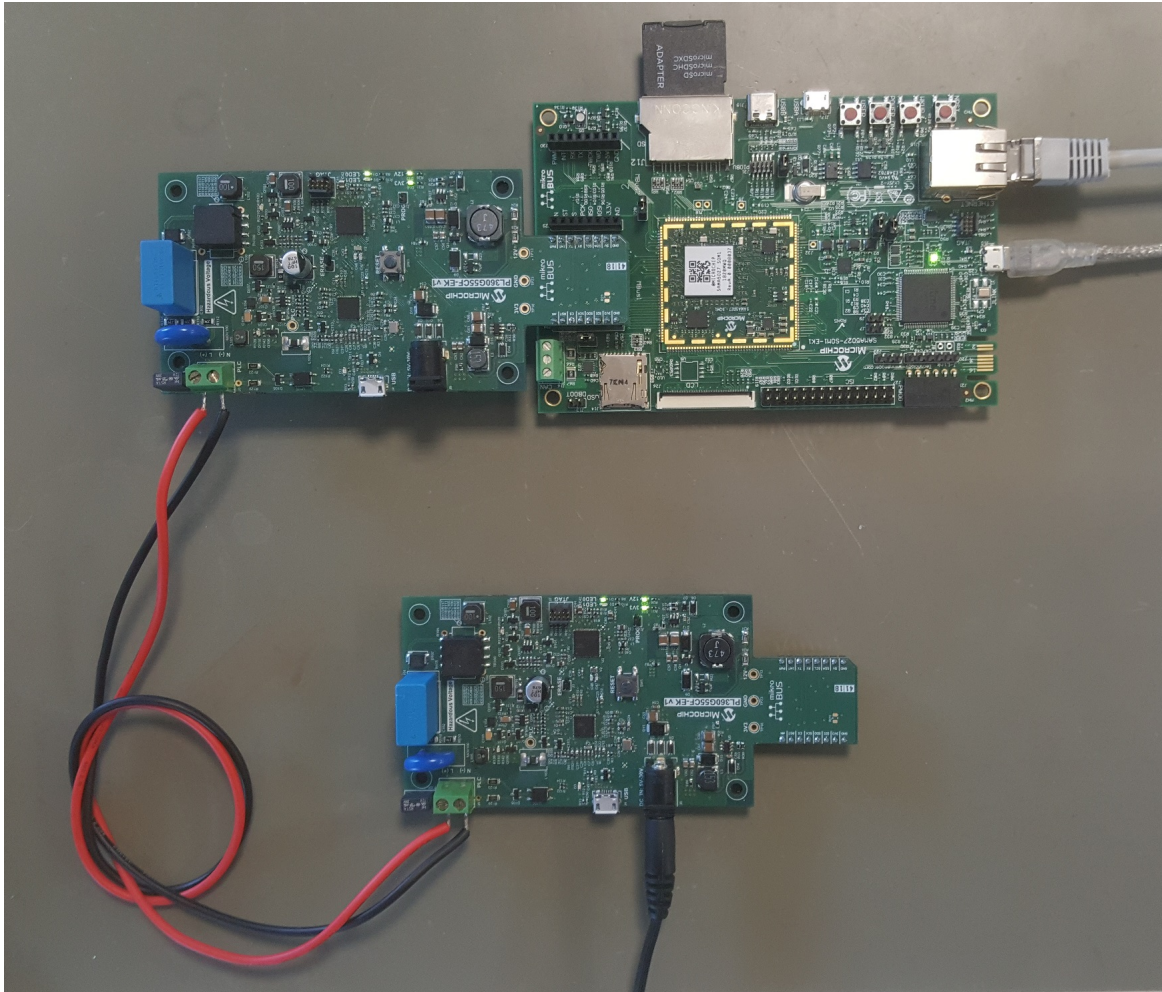
```
$ scp g3coordd root@<target-ip-addr>:/usr/bin
```

4. Start-up G3-PLC Linux as Coordinator

The G3-PLC coordinator running in Linux can be evaluated using a fully compliant G3-PLC network composed of:

- PAN Coordinator which runs in the SAMA5D27-SOM1-EK Linux board connected to PL360G55CF-EK, it takes care of the network formation and management
- PAN Device which runs on a PL360G55CF-EK and joins the network.

Figure 4-1. PLC Linux Coordinator Demo Physical Configuration



The PAN Device runs one of the examples of device included in the Microchip G3-PLC stack (for example, `dlms_app_dev` for PL360G55CF-EK). The firmware can be updated to perform embed sniffer capabilities which, in combination with the Microchip PLC Sniffer Tool, allows to monitor the PLC traffic and the content of the frames. To enable the embedded sniffer in the device, USI port must be configured and define `ENABLE_SNIFFER` must be enabled. In `conf_usi.h`:

```
#ifndef CONF_USI_H_INCLUDED
#define CONF_USI_H_INCLUDED

/* Enable Embedded Sniffer */
#define ENABLE_SNIFFER

#define USI_PORT_0      0

/* Port Communications configuration */
#define NUM_PORTS      1
/* In case of use USB_TYPE, refer to conf_usb.h in order to set baudrate by default */
#define PORT_0 CONF_PORT(USB_TYPE, 0, 230400, 1024, 1024)
```

```

/* In case of USI on Mikro BUS, comment previous line, and uncomment next line and
conf_busart_if.h configurations */
/* #define PORT_0 CONF_PORT(USART_TYPE, 0, 230400, 1024, 1024) */

/* Select PORT to sniffer phy iface */
#define PHY_SNIFFER_SERIAL_PORT          USI_PORT_0

#endif /* CONF_USI_H_INCLUDED */

```

Regarding the G3-PLC coordinator, on the SAMA5D27-SOM1-EK board terminal or console, it is required to initialize TUN interface to run the G3-PLC coordinator application. The first time after creating the binary image:

```

$ mkdir /dev/net
$ mknod /dev/net/tun c 10 200
$ chmod 0666 /dev/net/tun

```

And everytime the board is rebooted, before launching the coordinator application:

```

$ modprobe tun

```

Once the TUN interface is enabled, the g3coordd application can be launched:

```

# g3coordd -b CEN A -d /dev/ttyS1 -s 230400
atmel_usart fc00c000.serial: using dma0chan7 for rx DMA transfers
atmel_usart fc00c000.serial: using dma0chan8 for tx DMA transfers
[USI]:TTY port /dev/ttyS1 is open with speed 230400 and descriptor 3
00096075 INFO tun.c:123 Successfully created TUN device
000960D8 INFO app_adp_mng.c:587 Start modem initialization
000960D8 DBG app_adp_mng.c:589 Setting command 00: MAC_WRP_PIB_MANUF_EXTENDED_ADDRESS / 0
000961EA DBG app_adp_mng.c:589 Setting command 01: MAC_WRP_PIB_SHORT_ADDRESS / 0
000961FB DBG app_adp_mng.c:589 Setting command 02: ADP_IB_CONTEXT_INFORMATION_TABLE / 0
0009620F DBG app_adp_mng.c:589 Setting command 03: ADP_IB_CONTEXT_INFORMATION_TABLE / 1
00096224 DBG app_adp_mng.c:589 Setting command 04: ADP_IB_ROUTING_TABLE_ENTRY_TTL / 0
00096238 DBG app_adp_mng.c:589 Setting command 05: ADP_IB_MAX_JOIN_WAIT_TIME / 0
00096241 DBG app_adp_mng.c:589 Setting command 06: ADP_IB_MAX_HOPS / 0
0009626A INFO main.c:443 Microchip G3 Device version 0.0.3
0009626A INFO app_adp_mng.c:837 Show Versions:
0009627E INFO app_adp_mng.c:848 G3 STACK: 1.4.0 Date: 2019-2-4
00096288 INFO app_adp_mng.c:860 ADP : 1.6.4 Date: 2019-2-4
000962A6 INFO app_adp_mng.c:894 PHY : 02.04.02.36
000962CF INFO app_adp_mng.c:646 Starting coordinator...
000971D0 DBG main.c:488 Read from TUN...1, len 52
000971D0 DBG main.c:496 ADP Send Message OK, wait confirm.
00099660 DBG main.c:488 Read from TUN...2, len 52
00099660 DBG main.c:496 ADP Send Message OK, wait confirm.

```

When the devices on the PLC network starts joining to the G3-PLC coordinator, some debug information appears on g3coord console:

```

0009A8A9 INFO app_adp_mng.c:508 Updating Node List with 1 devices
0009A8A9 INFO app_adp_mng.c:511 Registered Short Address -> 0x1

```

By default, the coordinator will configure itself as a gateway for the network FD00:0:2:781D::/64. Connect to a board terminal (SSH or telnet) and show the g3plc IP interface configuration.

```

# ifconfig g3plc
g3plc Link encap:UNSPEC HWaddr 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00
inet6 addr: fd00:0:2:781d:1122:3344:5566:0/64 Scope:Global
inet6 addr: fe80::781d:ff:fe00:0/80 Scope:Link
UP POINTOPOINT RUNNING NOARP MULTICAST MTU:1280 Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:1 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:500
RX bytes:0 (0.0 B) TX bytes:48 (48.0 B)

```

If G3-PLC Devices are configured correctly it is possible to ping them using the Link Local Address. Ping command may include IPv6 capabilities:

```

# ping -6 -I g3plc FE80:0:0:0:781D:FF:FE00:0001 -i 1
PING FE80:0:0:0:781D:FF:FE00:0001(fe80::781d:ff:fe00:1) from fe80::781d:ff:fe00:0 g3plc: 56

```

```
data bytes
64 bytes from fe80::781d:ff:fe00:1: icmp_seq=1 ttl=64 time=138 ms
64 bytes from fe80::781d:ff:fe00:1: icmp_seq=2 ttl=64 time=75.2 ms
....
```

Some debug information appears on g3coord console:

```
0009C463 DBG main.c:488 Read from TUN...3, len 108
0009C463 DBG main.c:496 ADP Send Message OK, wait confirm.
0009C4C3 DBG app_adp_mng.c:237 AppAdpDataIndication DATA: 104 LQI: 51
0009C84C DBG main.c:488 Read from TUN...4, len 108
0009C84D DBG main.c:496 ADP Send Message OK, wait confirm.
0009C935 DBG app_adp_mng.c:237 AppAdpDataIndication DATA: 104 LQI: 48
0009CC35 DBG main.c:488 Read from TUN...5, len 108
0009CC36 DBG main.c:496 ADP Send Message OK, wait confirm.
0009CCC1 DBG app_adp_mng.c:237 AppAdpDataIndication DATA: 104 LQI: 88
0009D01E DBG main.c:488 Read from TUN...6, len 108
0009D01E DBG main.c:496 ADP Send Message OK, wait confirm.
0009D0BD DBG app_adp_mng.c:237 AppAdpDataIndication DATA: 104 LQI: 106
```

The default band configuration for the G3-PLC coordinator daemon is CENELEC_A (same as the embedded adp_mac_serialized project). If your hardware targets a different band, you must set the band option at boot. For example:

```
# g3coordd --band=FCC
```

Use the option -h (--help) for additional options.

A simple script could be written as application in order to ping all the G3-PLC devices present on the network. In this case, the package inotify-tools is required on the target to wait for changes on a temporary file defined on G3_PLC_NODE_LIST.

```
# cat /usr/bin/ping_app.sh#!/bin/sh
file_nodes=/tmp/g3plc_node_list
file_active_nodes=/tmp/g3plc_node_list_active

echo -e "[PING_APP] Configuring TUN interface"
if [ ! -c /dev/net/tun ]
then
    mkdir /dev/net
    mknod /dev/net/tun c 10 200
    chmod 0666 /dev/net/tun
fi
modprobe tun

echo -e "[PING_APP] Running G3-PLC Coordinator"
g3coordd --silent -b CEN_A &
sleep 5

echo -e "\r\n[PING_APP] Waiting for devices..."
while [ ! -f "$file_nodes" ]
do
    /usr/bin/inotifywait -qq 2 -e create "$(dirname $file_nodes)"
done
sleep 5
echo -e "[PING_APP] Node List created"

counter=1
while :
do
    echo -e "[PING_APP] Round $counter"
    while IFS=$'\n\r' read -r line || [ -n "$line" ]
    do
        ping -c 1 "$line" >> /dev/null
        if [ $? = 0 ]
        then
            echo -e "[PING_APP] Ping to $line OK"
            echo $line >> $file_active_nodes
            sort $file_active_nodes | uniq >> /tmp/o
            mv /tmp/o $file_active_nodes
        else
            echo -e "[PING_APP] Ping to $line failed. Waiting for a new route..."
        fi
    done
done
```

```

sed -i "$line/d" $file_active_nodes
sleep 60
fi
done < $file_nodes
sleep 5
let counter=counter+1
done

```

The G3-PLC traffic can be traced from the embedded sniffer in the G3-PLC device as seen on [Figure 4-2](#).

Figure 4-2. G3-PLC Bootstrapping seen on Microchip Multiprotocol PLC Sniffer

idFrame	Delta	TimeStamp	ModType	ModScheme	PduType	ToneMap	DT	LQI	Sym#	Duration	CmdType	Sec En	Sec Cnt	Seq #	Src Addr	Dest Addr	
4	4680,78	2018-09-18 14:55:54.954	BPSK_ROB	Differential	CMD	0x3F	SOF_NO_RESP	255	40	42,918	BREQ	false	-	0xE7	-	0xFFFF	13
5	1653,51	2018-09-18 14:55:56.707	BPSK_ROB	Differential	BCN	0x3F	SOF_NO_RESP	127	48	48,475	-	false	-	0x60	0x0000	-	18
6	10304,5	2018-09-18 14:56:07.030	BPSK_ROB	Differential	DAT	0x3F	SOF_RESP	255	76	67,938	LBP_JOINING	false	-	0xE8	0x0170530100410000	0x0000	34
7	5,556	2018-09-18 14:56:07.070	-	-	-	-	ACK	255	0	15,115	-	-	-	-	-	-	18
8	25,023	2018-09-18 14:56:07.135	BPSK_ROB	Differential	CMD	0x3F	SOF_RESP	126	68	62,375	TM_RSP	false	-	0x92	0x0000	0x0170530100410000	29
9	5,56	2018-09-18 14:56:07.155	-	-	-	-	ACK	255	0	15,118	-	-	-	-	-	-	9
10	25,016	2018-09-18 14:56:07.286	BPSK_ROB	Differential	DAT	0x3F	SOF_RESP	126	128	104,075	LBP_CHALLE...	false	-	0x93	0x0000	0x0170530100410000	63
11	5,56	2018-09-18 14:56:07.346	-	-	-	-	ACK	255	0	15,118	-	-	-	-	-	-	9
12	16,68	2018-09-18 14:56:07.386	BPSK	Differential	DAT	0x3F	SOF_RESP	255	20	29,018	LBP_JOINING	false	-	0xE9	0x0170530100410000	0x0000	118
13	5,558	2018-09-18 14:56:07.386	-	-	-	-	ACK	255	0	15,115	-	-	-	-	-	-	63
14	22,243	2018-09-18 14:56:07.572	BPSK_ROB	Differential	DAT	0x3F	SOF_RESP	128	228	173,575	LBP_CHALLE...	false	-	0x94	0x0000	0x0170530100410000	119
15	5,56	2018-09-18 14:56:07.632	-	-	-	-	ACK	255	0	15,118	-	-	-	-	-	-	9
16	19,46	2018-09-18 14:56:07.662	BPSK	Differential	DAT	0x3F	SOF_RESP	255	16	26,238	LBP_JOINING	false	-	0xEA	0x0170530100410000	0x0000	91
17	5,556	2018-09-18 14:56:07.662	-	-	-	-	ACK	255	0	15,115	-	-	-	-	-	-	119
18	16,683	2018-09-18 14:56:07.742	BPSK_ROB	Differential	DAT	0x3F	SOF_RESP	127	80	70,715	LBP_ACCEP...	false	-	0x95	0x0000	0x0170530100410000	36
19	5,56	2018-09-18 14:56:07.777	-	-	-	-	ACK	255	0	15,118	-	-	-	-	-	-	9
20	20,85	2018-09-18 14:56:07.857	BPSK_ROB	Differential	DAT	0x3F	SOF_NO_RESP	255	84	73,498	LNG_RREQ	true	22846	0xE8	0x0001	0xFFFF	38
21	19,456	2018-09-18 14:56:07.932	BPSK_ROB	Differential	DAT	0x3F	SOF_NO_RESP	127	84	73,495	LNG_RREQ	true	97871	0x96	0x0000	0xFFFF	38
22	117,897	2018-09-18 14:56:08.153	BPSK_ROB	Differential	DAT	0x3F	SOF_NO_RESP	126	92	79,055	-	true	97872	0x97	0x0000	0xFFFF	43
23	777,074	2018-09-18 14:56:09.000	BPSK_ROB	Differential	DAT	0x3F	SOF_RESP	126	84	73,495	LNG_RREP	true	97873	0x98	0x0000	0x0001	38
24	5,56	2018-09-18 14:56:09.081	-	-	-	-	ACK	255	0	15,118	-	-	-	-	-	-	9
25	16,68	2018-09-18 14:56:09.125	BPSK_ROB	Differential	CMD	0x3F	SOF_RESP	255	56	54,038	TM_RSP	false	-	0xEC	0x0001	0x0000	22
26	5,559	2018-09-18 14:56:09.125	-	-	-	-	ACK	255	0	15,115	-	-	-	-	-	-	38
27	2899,95	2018-09-18 14:56:12.038	BPSK	Differential	DAT	0x3F	SOF_RESP	255	12	23,458	LNG_RREP	true	22847	0xED	0x0001	0x0000	64
28	5,559	2018-09-18 14:56:12.098	-	-	-	-	ACK	255	0	15,115	-	-	-	-	-	-	38
29	6257,23	2018-09-18 14:56:18.357	BPSK	Differential	DAT	0x3F	SOF_RESP	132	20	29,015	-	true	97874	0x99	0x0000	0x0001	118
30	5,56	2018-09-18 14:56:18.412	-	-	-	-	ACK	255	0	15,118	-	-	-	-	-	-	9
31	157,07	2018-09-18 14:56:18.547	BPSK	Differential	DAT	0x3F	SOF_RESP	255	16	26,238	-	true	22848	0xEE	0x0001	0x0000	91
32	5,559	2018-09-18 14:56:18.602	-	-	-	-	ACK	255	0	15,115	-	-	-	-	-	-	118
33	9745,63	2018-09-18 14:56:28.346	BPSK	Differential	DAT	0x3F	SOF_RESP	128	20	29,015	-	true	97875	0x9A	0x0000	0x0001	118
34	5,56	2018-09-18 14:56:28.486	-	-	-	-	ACK	255	0	15,118	-	-	-	-	-	-	9
35	61,16	2018-09-18 14:56:28.486	BPSK	Differential	DAT	0x3F	SOF_RESP	255	16	26,238	-	true	22849	0xEF	0x0001	0x0000	91
36	5,557	2018-09-18 14:56:28.486	-	-	-	-	ACK	255	0	15,115	-	-	-	-	-	-	118
37	9850,34	2018-09-18 14:56:38.352	BPSK	Differential	DAT	0x3F	SOF_RESP	124	20	29,015	-	true	97876	0x9B	0x0000	0x0001	118
38	5,56	2018-09-18 14:56:38.467	-	-	-	-	ACK	255	0	15,118	-	-	-	-	-	-	9
39	164,02	2018-09-18 14:56:38.562	BPSK	Differential	DAT	0x3F	SOF_RESP	255	16	26,238	-	true	22850	0xF0	0x0001	0x0000	91
40	5,559	2018-09-18 14:56:38.627	-	-	-	-	ACK	255	0	15,115	-	-	-	-	-	-	118
41	2771,53	2018-09-18 14:56:41.431	BPSK_ROB	Differential	DAT	0x3F	SOF_NO_RESP	127	92	79,055	-	true	97877	0x9C	0x0000	0xFFFF	43
42	6893,15	2018-09-18 14:56:48.361	BPSK	Differential	DAT	0x3F	SOF_RESP	130	20	29,015	-	true	97878	0x9D	0x0000	0x0001	118
43	5,56	2018-09-18 14:56:48.496	-	-	-	-	ACK	255	0	15,118	-	-	-	-	-	-	9
44	58,38	2018-09-18 14:56:48.496	BPSK	Differential	DAT	0x3F	SOF_RESP	255	16	26,238	-	true	22851	0xF1	0x0001	0x0000	91

5. Abbreviations

ADP	Adaptation
DLMS	Device Language Message Specification
MAC	Medium Access Channel
PCB	Printed Circuit Board
PLC	Power Line Communications
USI	Universal Serial Interface

6. Revision History

6.1 Rev A - 07/2019

Document	Initial document release.
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6.2 Rev B - 01/2020

1. Hardware Description	<ul style="list-style-type: none">• Updated Figure 1-2.• Added SD card requirements.
3. Features of Microchip G3-PLC Linux Coordinator Application	<ul style="list-style-type: none">• Updated steps in section 3.1
4. Start-up G3-PLC Linux as Coordinator	<ul style="list-style-type: none">• Added configuration of embedded sniffer.• Added initialization of TUN interface.• New example script.

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