



S32G Linux PFE Driver User's Manual

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Chapter 1

Revision History

Revision	Change Description
preEAR 0.4.0	Initial version for preEAR (FPGA/x86 platform) [JPet]
preEAR 0.4.1	Added VDK info [JPet]
preEAR 0.4.3	Removed VDK, Added S32G [JPet]
EAR 0.8.0	Added device-tree config [JPet]
EAR 0.8.0 Patch 1	Added libfci [JPet]
BETA 0.9.0	DTS update for kernel 5.4-rt [JPet]
BETA 0.9.1	Added Master/Slave [JPet]
BETA 0.9.2	Added performance info [JPet]

Table 1.1: Revision History

Chapter 2

Introduction

The Linux PFE driver is, in general, an OS-specific SW component responsible for the complex PFE management. It consists of three main functional blocks:

- The platform driver
This part covers the initial, low-level PFE HW bring-up, configuration, firmware upload, and the SW representation of the PFE HW components. This part can be described as a low-level PFE driver providing the interface to the hardware (including the firmware).
- The data-path driver
Data-path driver covers tasks related to the Ethernet data traffic in terms of passing the packets between the PFE and the networking stack. This includes the implementation of the Host Interface (HIF) driver and connection with the host OS-provided the networking stack.
- Control path driver
The block in charge of the functionality related to runtime PFE engine configuration and monitoring, implementing the Fast Control Interface (FCI) endpoint which is accessible from the user-space through related FCI library.

The driver runs within the target host OS environment and connects the PFE with networking stack. It provides access to physical Ethernet interfaces via exposing logical interfaces to the OS, and the OS together with user's applications can use the Ethernet connectivity via standard OS-provided interfaces (i.e. network sockets).

Chapter 3

Building Procedure

3.1 Building the driver

The PFE driver consists of number of smaller software modules. The main module producing the final driver is called *linux-pfeng* and depends on all the others. Successful build gives the final driver library *pfeng.ko* which is an Ethernet driver for particular Linux kernel. Its location within the project tree in `sw/linux-pfeng/`. There are two ways to build the driver:

1. Integrated build by NXP Automotive Linux BSP, powered by Yocto
2. Standalone

3.1.1 Variant 1: Building within NXP Auto Linux BSP source tree by Yocto

1. As prerequisite, save the PFE firmware files to any location on the local disk. Ask NXP representative for PFE firmware package.
2. Build standard NXP Auto Linux BSP to check that all necessary components are ready. This step is not only for verification but it precompiles most of necessary part of BSP which will be used later for creating sdcard image with included pfeng Linux driver.

3. Configure additional component by adding the following two lines to the `conf/local.conf`

```
DISTRO_FEATURES_append = " pfe "  
PFE_LOCAL_FIRMWARE_DIR = "<some directory path where the fw file was  
saved>"
```

4. Rebuild BSP to get PFE driver + firmware included in the sdcard image

3.1.2 Variant 2: Building standalone

1. As prerequisite check all necessary development requirements:
 - (a) Host development GNU toolchain, including GNU-cc, GNU-make
 - (b) Linux kernel development files
2. Go to `sw/linux-pfeng/`.

3. Make sure that the following environment variables are set and points to the right directories:

- (a) KERNELDIR

The directory where the Linux kernel development files are located.

- (b) Optionally also PLATFORM

The name of the GNU toolchain platform. In case of NXP Auto Linux BSP, it is "aarch64-linux-gnu"

4. Clean working directories:

```
make KERNELDIR=<path to kernel> PLATFORM=aarch64-linux-gnu drv-clean
```

5. Build the driver:

```
make KERNELDIR=<path to kernel> PLATFORM=aarch64-linux-gnu all
```

Chapter 4


Usage

4.1 Prerequisites

4.1.1 NXP S32G274A silicon platform EVB, RDB or RDB2

For usage the software on S32G EVB or RDB/RDB2 boards, the following shall be fulfilled:

- Compatible PFE firmware files.

 *The compatibility requirements can be find in the driver public repository:
<https://source.codeaurora.org/external/autobsp32/extra/pfeng>*

- Auto Linux BSP version 27.0 or higher for creation of sdcard bootable image

 *Note that PFE firmware is being delivered as a standalone product package.*

4.2 Supported development boards

NXP offers two development boards for S32G274A:

1. S32G-VNP-EVB
2. S32G-VNP-RDB/S32G-VNP-RDB2

Please refer to board specific user guide to check possible ethernet connectivity. Also check 'NXP Automotive Linux BSP User Manual' which provides comprehensive information for ethernet controllers, including supported configurations for U-boot and Linux.

4.3 Running the driver

1. The *pfeng.ko* driver is embedded in the Auto Linux BSP sdcard image and as such is automatically loaded on Linux startup.
2. To check available network interfaces:

```
root@s32g274aevb:~# ifconfig -a
```

there should be some, based on config, *pfeX* interfaces.

3. Configure the IP addresses and bring the interfaces up by executing:

```
root@s32g274aevb:~# ifconfig pfe<0-2> <interface_ip_address>/<mask>
```

4. The *ping* utility can be used to test the connection:

```
root@s32g274aevb:~# ping <remote_ip_address>
```

4.4 The driver configuration - device tree

The driver is configurable by changes in the device-tree pfeng node. Usually, the device tree files are using multi-level organization, for example the *fsl-s32g274a-evb.dtb* is built by integration:

1. Family DT file *fsl-s32-gen1.dtsi*
2. SoC DT file *fsl-s32g274a.dtsi*
3. Board specific DT file *fsl-s32g274a-evb.dts*

Listing 4.1: PFE device tree node example

```
*
* Copyright 2020 NXP
*
* NXP S32G274A PFE networking accelerator (pfeng)
*

Required properties:
- compatible : Should be "fsl,s32g274a-pfeng"
- reg : Address and length of the register set for the device
- interrupts : Should contain all pfeng interrupts: hif0..hif3,nocpy,bmu,
  upegpt,safety
- clocks : Should contain at least: pfe_sys, pfe_pe, xbar
- memory-region : Physical address space for PFE buffers, must be in the
  range 0x00020000 - 0xbfffffff

Optional properties:
- fsl,fw-class-name : PFE CLASS firmware filename
- fsl,fw-util-name : PFE UTIL firmware filename
- fsl,pfeng-master-hif-channel : [slave only] The number of master's HIF
  channel (0-3)

Required subnode:
- ethernet : specifies the logical network interface

Requires properties for 'ethernet' subnode:
- compatible : Should be "fsl,pfeng-logif"
- reg : Small number, indexing the network interfaces
- fsl,pfeng-hif-channel : The number of HIF channel (0-3)
- phy-mode : See ethernet.txt file in the same directory
- fsl,pfeng-if-name : Logical interface name visible in the Linux
```


The driver configuration - device tree

- fsl,pfeng-ethernet-id : PFE Ethernet id where the interface will be linked to

Optional properties for 'ethernet' subnode:

- fsl,pfeng-ihc : [master/slave only] Declares the interface for IHC traffic
- local-mac-address : MAC address
- phy-handle : phandle to the PHY device connected to this device.
- fixed-link : Assume a fixed link. See fixed-link.txt in the same directory.
Use instead of phy-handle.

Optional subnode for 'ethernet':

- mdio : specifies the mdio bus, used as a container for phy nodes according to phy.txt in the same directory

Requires properties for 'mdio' subnode:

- compatible = Should be "fsl,pfeng-mdio"

Example:

```
pfe@46080000 {
    compatible = "fsl,s32g274a-pfeng";
    reg = <0x0 0x46000000 0x0 0x1000000>, /* PFE controller */
        <0x0 0x4007ca00 0x0 0x4>, /* S32G274a syscon */
        <0x0 0x83400000 0x0 0xc00000>; /* PFE DDR 12M */
    #address-cells = <1>;
    #size-cells = <0>;
    memory-region = <&pfe_reserved>;
    interrupt-parent = <&gic>;
    interrupts = <0 190 1>, /* hif0 */
        <0 191 1>, /* hif1 */
        <0 192 1>, /* hif2 */
        <0 193 1>, /* hif3 */
        <0 194 1>, /* bmu */
        <0 195 1>, /* nocpy */
        <0 196 1>, /* upe/gpt */
        <0 197 1>; /* safety */
    interrupt-names = "hif0", "hif1", "hif2", "hif3",
        "bmu", "nocpy", "upegpt", "safety";
    clocks = <&clks S32GEN1_CLK_PFE_SYS>,
        <&clks S32GEN1_CLK_PFE_PE>,
        <&clks S32GEN1_CLK_XBAR>;
    clock-names = "pfe_sys", "pfe_pe", "xbar";
    fsl,fw-class-name = "s32g_pfe_class.fw";
    fsl,fw-util-name = "s32g_pfe_util.fw";

    /* EMAC 0 */
    pfe0_if: ethernet@0 {
        compatible = "fsl,pfeng-logif";
        #address-cells = <1>;
        #size-cells = <0>;
        reg = <0>; /* If id */
        local-mac-address = [ 00 04 9F BE EF 00 ];
        fsl,pfeng-if-name = "pfe0";
        fsl,pfeng-hif-channel = <0>; /* HIF channel 0 */
        fsl,pfeng-ethernet-id = <0>; /* EMAC 0 */
        phy-mode = "sgmii";
        phy-handle = <&anyphy1>;
    }
}
```


```

/* MDIO on EMAC 0 */
pfe0_mdio: mdio@0 {
    /* on EVB occupied by USB ULPI */
    status = "disabled";
    compatible = "fsl,pfeng-mdio";
    #address-cells = <1>;
    #size-cells = <0>;
    reg = <0x0>;
};

/* EMAC 1 */
pfel_if: ethernet@1 {
    compatible = "fsl,pfeng-logif";
    #address-cells = <1>;
    #size-cells = <0>;
    reg = <1>; /* If id */
    local-mac-address = [ 00 04 9F BE EF 01 ];
    fsl,pfeng-if-name = "pfel";
    fsl,pfeng-hif-channel = <1>; /* HIF channel 1 */
    fsl,pfeng-ethernet-id = <1>; /* EMAC 1 */
    phy-mode = "rgmii";
    phy-handle = <&anyphy2>;
    pinctrl-names = "default";
    pinctrl-0 = <&pinctrl0_pfel_rgmii_c>,
                <&pinctrl1_pfel_rgmii_c>;

/* MDIO on EMAC 1 */
pfel_mdio: mdio@0 {
    compatible = "fsl,pfeng-mdio";
    #address-cells = <1>;
    #size-cells = <0>;
    reg = <0x1>;
    pinctrl-names = "default";
    pinctrl-0 = <&pinctrl0_pfel_mdio_c>,
                <&pinctrl1_pfel_mdio_c>;
    anyphy1: ethernet-phy@1 {
        reg = <1>;
    };
    anyphy2: ethernet-phy@2 {
        reg = <2>;
    };
};
};


```

 *The driver requires per-interface exclusive HIF channel. Use the property 'fsl,pfeng-hif-channel' to fulfill it.*

4.5 Performance consideration

The driver is build with rather conservative setup. If there is requirement to gain highest possible throughput on host interface, several options exist to enhance performance, loosig

other features or resources:

 *Only S32G2 cut2.0 or higher can be used for performance enhancements.*

- compile driver for cut 2.0
 - Auto Linux BSP image contains the pfeng.ko driver build for cut 1.1, what enables support for S32G2 errata and results in lower throughput. Rebuild with compile option `PFE_CFG_IP_VERSION=PFE_CFG_IP_VERSION_NPU_7_14a` to disable all errata support for S32G2.
- device coherency
 - Enable PFE coherency support in driver by adding 'dma-coherent' property to the pfe node in the device tree.
- double key ring size
 - Better throughput can be achieved by doubling HIF channel ring size. By default there is 256. It's compile time option which must be changed in source code header file 'pfe_platform/public/pfe_platform_cfg.h', in named constant `PFE_HIF_RING_CFG_LENGTH`. Please note that the restriction applies: not all interfaces can be enabled or reserved memory region has to be enlarged in device tree.
- mem=2g
 - Restrict Linux kernel memory to 2G limit. It minimizes bounce buffering on TX. Disadvantage: waste memory.

Chapter 5

Master-Slave feature

5.1 Prerequisite

The driver can run in multiple instances within the same system to allow sharing the PFE-provided connectivity using dedicated host interfaces. To enable Master-Slave, the driver gets extended to two binaries, *pfeng.ko* which additionally contains Inter-HIF-communication (aka 'IHC') support and which acts as Master and *pfeng-slave.ko*, which also contains IHC, but has lack of direct PFE controller manageability.

 *Master-Slave feature requires additional configuration in device tree*

5.2 Master

To build PFE driver with Master functionality, additional compile-time option is required:

```
make <options> PFE_CFG_MULTI_INSTANCE_SUPPORT=1 PFE_CFG_PFE_MASTER=1 ...
```

The Master requires marking one of the configured network interface for IHC transport in device tree by setting *fsl,pfeng-ihc* property, for example:

```
&pfe0_if {
    fsl,pfeng-ihc;
    fsl,pfeng-hif-channel = <0>;
    phy-mode = "sgmii";
    phy-handle = <&mdio_a_phy4>;
};
```

5.3 Slave

To build PFE driver with Slave functionality, additional compile-time option is required:

```
make <options> PFE_CFG_MULTI_INSTANCE_SUPPORT=1 PFE_CFG_PFE_MASTER=0 ...
```

The Slave requires two configuration options in device tree:

- setting global configuration option 'fsl,pfeng-master-hif-channel' with Master's HIF channel number (see example in Master section). The option can be overwritten by command line parameter *master_ihc_chnl*.

- marking one of the configured network interface for IHC transport in device tree by setting *fsl,pfeng-ihc* property.

Slave example:

```
pfeslave@46000000 {
    compatible = "fsl,s32g274a-pfeng-slave";
    reg = <0x0 0x46000000 0x0 0x1000000>, /* PFE controller
        */
        <0x0 0x4007ca00 0x0 0x4>; /* S32G274a
        syscon */
    #address-cells = <1>;
    #size-cells = <0>;
    interrupt-parent = <&gic>;
    interrupts = <0 190 1>, /* hif0 */
        <0 191 1>, /* hif1 */
        <0 192 1>, /* hif2 */
        <0 193 1>, /* hif3 */
        <0 194 1>, /* bmu */
        <0 195 1>; /* nocpy */
    interrupt-names = "hif0", "hif1", "hif2", "hif3",
        "bmu", "nocpy";
    memory-region = <&pfe_reserved_slave>;
    fsl,pfeng-master-hif-channel = <0>;

    /* EMAC 1 */
    pfelsl_if: ethernet@1 {
        compatible = "fsl,pfeng-logif";
        #address-cells = <1>;
        #size-cells = <0>;
        status = "okay";
        reg = <1>;
        local-mac-address = [ 00 04 9F BE EF F1 ];
        fsl,pfeng-if-name = "pfelsl";
        fsl,pfeng-eth-id = <1>; /* Phy IF (EMAC) id */
        fsl,pfeng-ihc;
        fsl,pfeng-hif-channel = <3>;
        phy-mode = "internal";
    };
};
```

5.4 Running

When running a master-slave scenario, following points apply:

- Master driver must always be executed first to allow slave drivers to connect to it during their start-up phase.
- Slave driver(s) configure the PFE to ensure that packets can reach the driver. The PFE then distributes traffic to particular driver instances using destination MAC address of received packets following given rules:
 - Packets received via PFE EMAC interfaces with destination MAC address matching some running slave driver instance are delivered to that instance.
 - All remaining traffic is delivered to the master driver instance.

-
- Default MAC address-based traffic distribution can be changed using FCI.
 - When master driver is reset, all slaves must be subsequently reset too

Chapter 6

LibFCI

6.1 The libfci

Additional features provided by the PFE can be managed using FCI API. The driver release package contains library sources which can be used to control PFE from custom user's application. Details about usage of the library can be found in '*FCI API Reference*' document.

6.2 Building libfci library

The simplest way, how to get in touch with libfci framework, is using the Auto Linux BSP facilities. The BSP contains libfci recipe in `meta-alb/recipes-extended` subdirectory, which is intended for quick jump-in to the FCI development. By default, the libfci is not enabled, so the first step is to create libfci.a library:

```
user@dev:~/fsl-auto-yocto-bsp/build_s32g274aevb$ bitbake -c compile libfci
```

6.3 Entering Yocto development environment

Yocto offers extra task called devshell. The task will deposit all the libfci source code into a directory, apply all patches included in the recipe, and then open a terminal in that directory:

```
user@dev:~/fsl-auto-yocto-bsp/build_s32g274aevb$ bitbake -c devshell libfci
```

When invoked, all environmental variables are set up exactly like for compilation. Use predefined `$CC`, `$CXX`, `$PATH`. The libfci.a library, which was compiled in previous step, is located in `sw/xfci/libfci/build/release` directory, what can be checked by *find* command, inside devshell terminal:

```
root@dev:~/fsl-auto-.../libfci/0.9.1-r0/git# find . -name libfci.a
./sw/xfci/libfci/build/release/libfci.a
```

The same way it can be checked for required header files:

```
root@dev:~/fsl-auto-.../libfci/0.9.1-r0/git# find . -name libfci.h
./sw/xfci/libfci/public/libfci.h
```

The above information is enough to have all necessary bits for libfci-enabled application development.