APPLICATION NOTE

REVISION 0.2 DATE 2017/05/15

DEPLOYING IPSEC GATEWAY WITH INTEL® QUICKASSIST ON THE ADVANTECH FWA-5020U-D0A1R NETWORK APPLIANCE

Revision History

Date [mm/dd/yyyy]	Revision	Modifications
04/20/2017	0.1	Initial version
05/11/2017	0.2	Revied by PAE

Description

This application note describes how to deploy QAT with IPSec gateway on the FWA-5020U-D0A1R server. It is based on the standard process that DPDK.org provides and highlights any additional steps required.

We appreciate your input

Please let us know if you consider any aspect of this application note needs improving or correcting. We appreciate your valuable input in helping make our products and documentation better.

Please send all such comments in writing to: ncg@advantech.com

Acknowledgements

Xeon, QuickAssist and Intel are trademarked by Intel Corp.

All other product names or trademarks are properties of their respective owners.

1. EQUIPMENT SETUP

1.1 Hardware used

An off-the-shelve Advantech system with Intel QuckAssist Technology (QAT) is required. In this document, The network appliance FWA-5020U-D0A1R with PCIe-3021-00E card are selected for demonstration. The PCIe-3021-00E is an external PCIe card with Intel coletocreek 8955 chipset accompanied with Intel QAT inside.

The QAT polling mode driver (PMD), which is part of Intel DPDK, provides a poll mode crypto driver with support for Intel QuickAssist Technology DH895xxC, Intel QuickAssist Technology C62x and Intel QuickAssist Technology C3xxx hardware accelerator. In this demonstration, the QAT card adopts Intel QuickAssist Technology DH895xxC hardware accelerator.

For the IPSec gateway with QAT demonstration, at least four NIC ports are used. The ports are classified as *Protected* and *Unprotected*. Traffic received on an Unprotected port is considered as Inbound, while traffic received on a Protected port is considered as Outbound.

Two of NIC ports play the rule of outbound traffic, while other two ports are in charge of inbound traffic. Ciphering algorithm and authentication algorithm are involved during outbound traffic when packets flows from protected area to unprotected area. Similarly, deciphering and authentication are needed for inbound traffic. Please refer to the fig below.

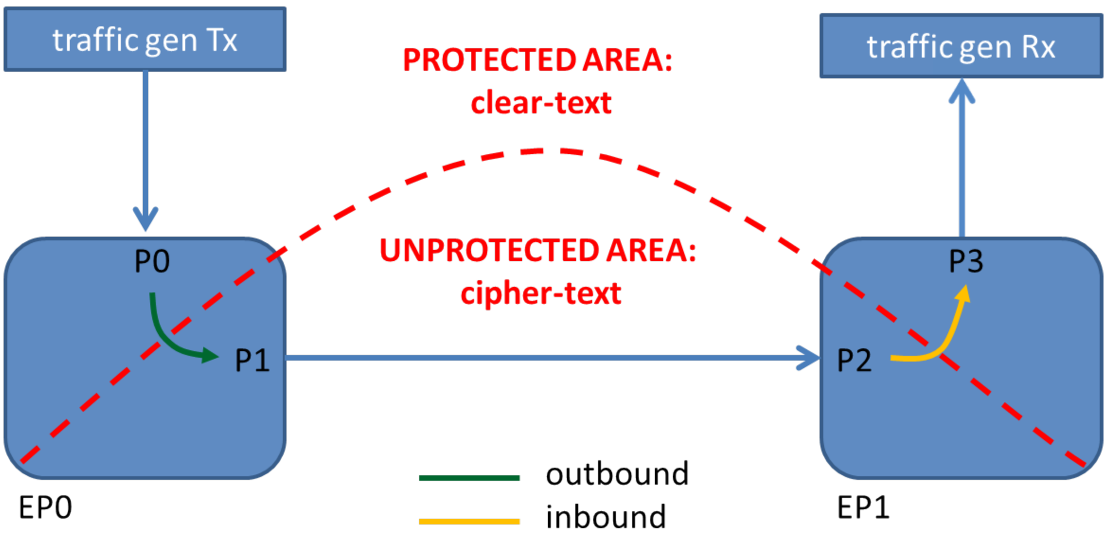


Fig1: inbound traffic and outbound traffic

If the demonstration is done by a single machine, at least six NIC ports are needed. Two extra NIC ports are used for packet generator sending and receiving packets. The architecture is shown below. It’s the final architecture for following illustration.

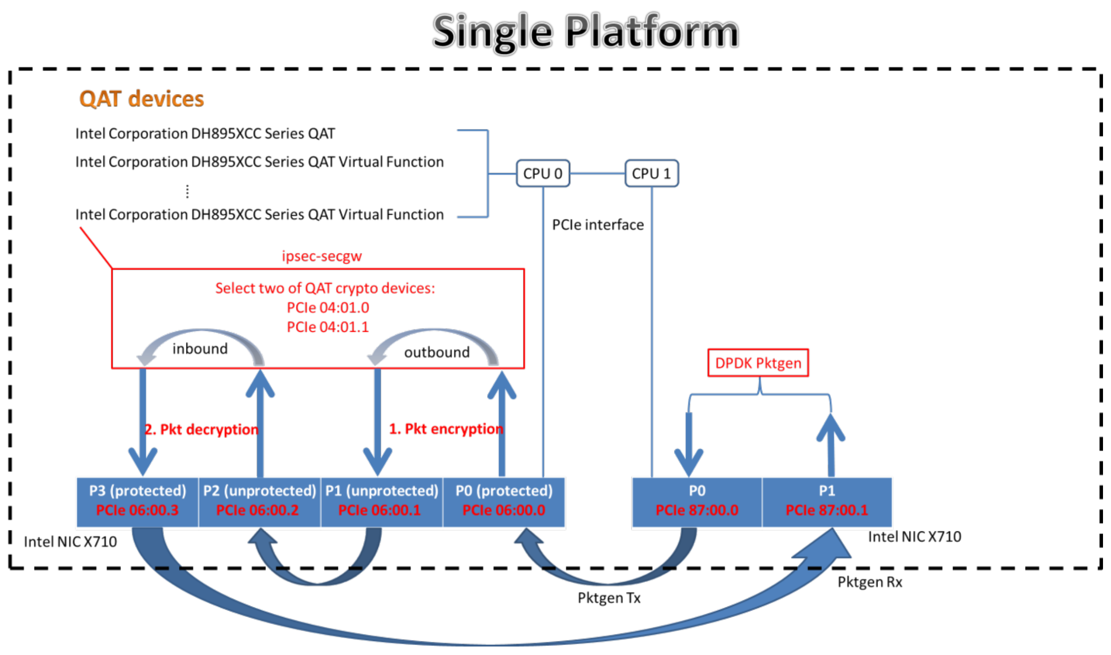

Single Platform
QAT devices
Intel Corporation DH895XCC Series QAT
Intel Corporation DH895XCC Series QAT Virtual Function
Intel Corporation DH895XCC Series QAT Virtual Function
CPU 0
CPU 1
PCIe interface
ipsec-secgw
Select two of QAT crypto devices:
PCIe 04:01.0
PCIe 04:01.1
inbound
outbound
DPDK Pktgen
2. Pkt decryption
1. Pkt encryption
P3 (protected) PCIe 06:00.3
P2 (unprotected) PCIe 06:00.2
P1 (unprotected) PCIe 06:00.1
P0 (protected) PCIe 06:00.0
P0 PCIe 87:00.0
P1 PCIe 87:00.1
Intel NIC X710
Intel NIC X710
Pktgen Tx
Pktgen Rx

Fig2: Demonstration scenario

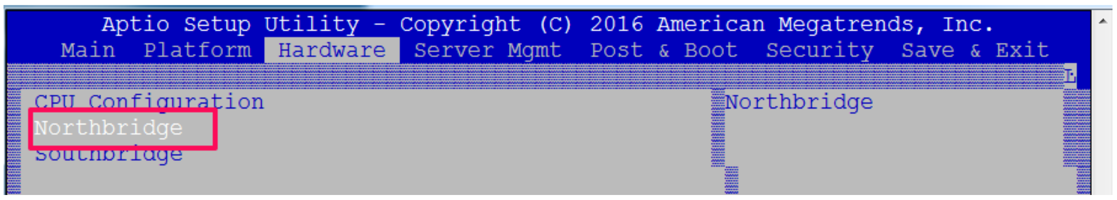
Here we prepared 2 Advantech Network Mezzanine Cards (NMC) to comply with the requirement, each contains Intel NIC X710 chipset with 10Gb Ethernet capability compatible with the i40e driver.

The summary of the environment list below for reference:

CPU	Intel Broadwell-EP Xeon E5-2680 v4@ 2.40GHz , 14 cores per socket, 2 threads pre core supported, which 28 cores per socket. 2 sockets on board, 56 cores totally.
X710 for pktgen	Two ports for packet generator, PCIe address: 87:00.0 87:00.1
X710 for ipsec-secgw	Two ports for outbound traffic, PCIe address: 06:00.0 06:00.1 Two ports for inbound traffic, PCIe address: 06:00.2 06:00.3
QAT, DH895xcc	Two virtual QAT crypto devices, PCIe address: 04:01.0 04:01.1

1.2 BIOS configuration requirement

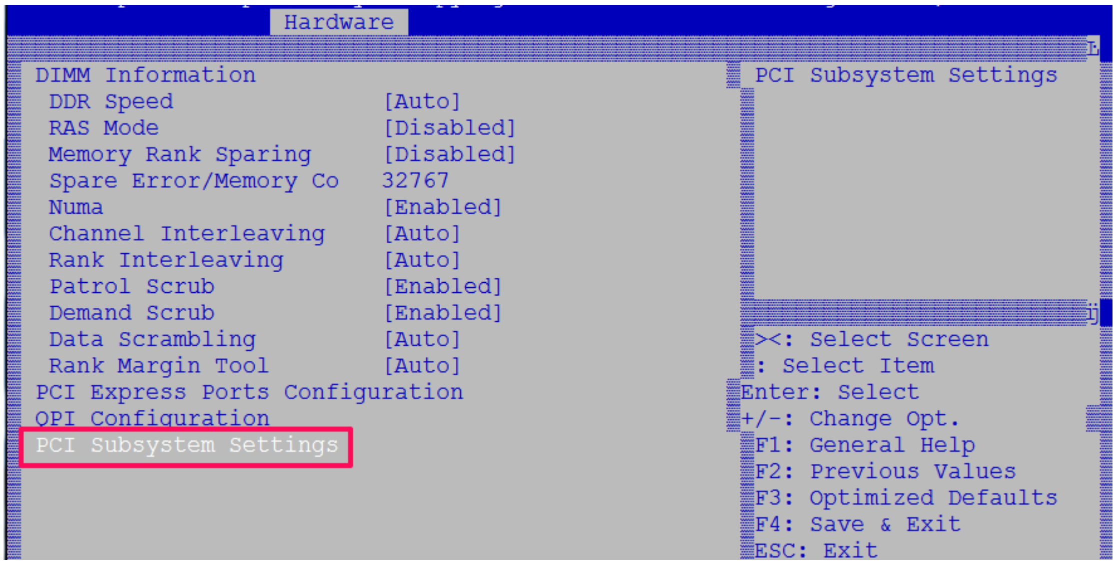
For the majority of platforms, no special BIOS settings are needed to use basic DPDK functionality. However, for usage of DPDK QAT PMD, an SRIOV-enabled QAT kernel driver is required. The Virtual Function (VF) devices exposed by this driver will be used by QAT PMD. Ensure that SRIOV is enabled and VT-d is disabled in the BIOS setting menu described below.



```
        Aptio Setup Utility - Copyright (C) 2016 American Megatrends, Inc.
     Main  Platform  Hardware  Server Mgmt  Post & Boot  Security  Save & Exit

  CPU Configuration                                 Northbridge
  Northbridge
  Southbridge
```

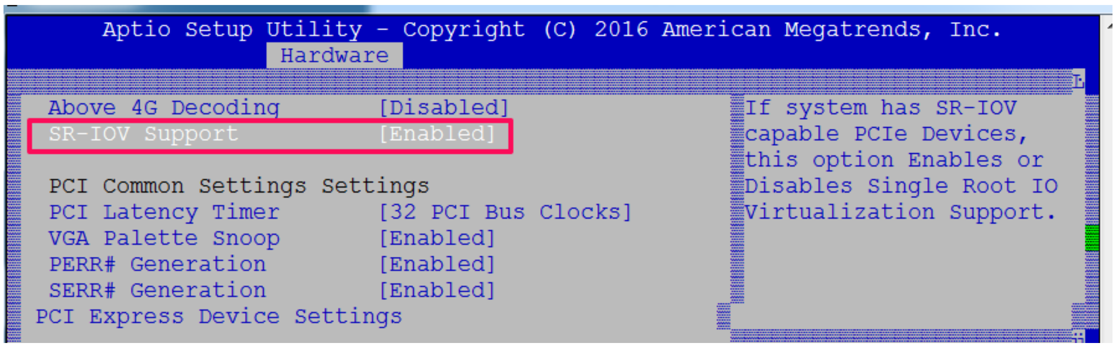
Fig3: Enable SRIOV step-1



```
                     Hardware

  DIMM Information                                    PCI Subsystem Settings
   DDR Speed                [Auto]
   RAS Mode                 [Disabled]
   Memory Rank Sparing      [Disabled]
   Spare Error/Memory Co    32767
   Numa                     [Enabled]
   Channel Interleaving     [Auto]
   Rank Interleaving        [Auto]
   Patrol Scrub             [Enabled]
   Demand Scrub             [Enabled]
   Data Scrambling          [Auto]                     ><: Select Screen
   Rank Margin Tool         [Auto]                     : Select Item
  PCI Express Ports Configuration                     Enter: Select
  QPI Configuration                                   +/-: Change Opt.
  PCI Subsystem Settings                               F1: General Help
                                                       F2: Previous Values
                                                       F3: Optimized Defaults
                                                       F4: Save & Exit
                                                       ESC: Exit
```

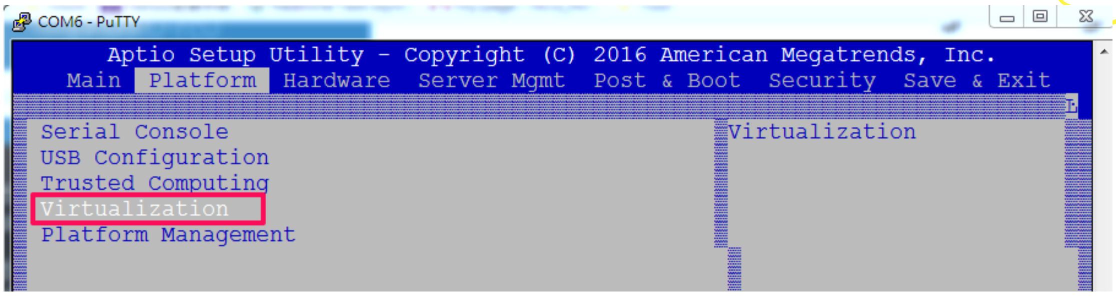
Fig4: Enable SRIOV step-2



```
        Aptio Setup Utility - Copyright (C) 2016 American Megatrends, Inc.
                     Hardware

   Above 4G Decoding        [Disabled]               If system has SR-IOV
   SR-IOV Support           [Enabled]                capable PCIe Devices,
                                                     this option Enables or
   PCI Common Settings Settings                      Disables Single Root IO
   PCI Latency Timer        [32 PCI Bus Clocks]      Virtualization Support.
   VGA Palette Snoop        [Enabled]
   PERR# Generation         [Enabled]
   SERR# Generation         [Enabled]
  PCI Express Device Settings
```

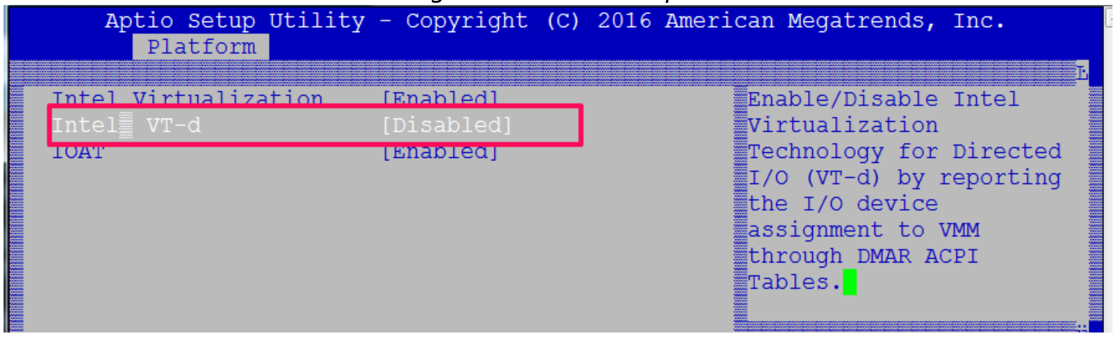
Fig5: Enable SRIOV step-3



```
COM6 - PuTTY
        Aptio Setup Utility - Copyright (C) 2016 American Megatrends, Inc.
    Main  Platform  Hardware  Server Mgmt  Post & Boot  Security  Save & Exit

   Serial Console                                        Virtualization
   USB Configuration
   Trusted Computing
   Virtualization
   Platform Management
```

Fig6: Disable VT-d step-1



```
        Aptio Setup Utility - Copyright (C) 2016 American Megatrends, Inc.
                   Platform

    Intel Virtualization     [Enabled]                Enable/Disable Intel
    Intel VT-d               [Disabled]               Virtualization
    IOAT                     [Enabled]                Technology for Directed
                                                      I/O (VT-d) by reporting
                                                      the I/O device
                                                      assignment to VMM
                                                      through DMAR ACPI
                                                      Tables.
```

Fig7: Disable VT-d step-2

1.3 Software requirement

Tools/packages that are required for compiling environment. In the demonstration, platform OS is CentOS 7.3 with kernel verion 3.10.0-514.el7.x86_64. Please make sure following packages are well-installed before following DPDK/QAT build.

- GNU make.
- coreutils: cmp, sed, grep, arch, etc.
- gcc: versions 4.9 or later is recommended for all platforms.
- libc headers, often packaged as gcc-multilib (glibc-devel.i686 / libc6-dev-i386; glibc-devel.x86_64 / libc6-dev for 64-bit compilation on Intel architecture; glibc-devel.ppc64 for 64 bit IBM Power architecture;)
- Linux kernel headers or sources required to build kernel modules. (kernel - devel.x86_64; kernel - devel.ppc64). In CentOS, it can be easily obtained by:
  - # yum install kernel-headers-`uname -r`
  - # yum install kernel-src-`uname -r`
  - # yum install kernel-devel-`uname -r`
- Python, version 2.7+ or 3.2+, to use various helper scripts included in the DPDK package.
- Development Tools
- pciutils
- libudev-devel
- boost-devel
- zlib-devel
- openssl-devel
- libpcap-devel
- lua-static

1.4 Build DPDK Poll Mode Driver with QAT Crypto Devices

First, uncompress the DPDK archive and move to the uncompressed DPDK source directory, where the source tarball can be found at DPDK.org @ http://dpdk.org/download

The latest major version is 17.02 as of writing this. Given dpdk, pktgen and qat source packages are located at /root/ipsec_demo.

```
# cd  /root/ipsec_demo
# tar xJf dpdk-17.02.tar.xz
# cd dpdk-17.02
```

The DPDK is composed of several directories:

- lib: Source code of DPDK libraries
- drivers: Source code of DPDK poll-mode drivers
- app: Source code of DPDK applications (automatic tests)
- examples: Source code of DPDK application examples
- config, buildtools, mk: Framework-related makefiles, scripts and configuration

The format of a DPDK target is: **ARCH-MACHINE-EXECENV-TOOLCHAIN**

where:

- ARCH can be: i686, x86_64, ppc_64
- MACHINE can be: native, power8
- EXECENV can be: linuxapp, bsdapp
- TOOLCHAIN can be: gcc, icc

The targets to be installed depend on the 32-bit and/or 64-bit packages and compilers installed on the host. Available targets can be found in the DPDK/config directory. The defconfig_ prefix should not be used.

To install and make targets, use the **make install T=<target>** command in the top-level DPDK directory. Before making DPDK PMD, we need to let QAT supported by PMD be enabled firstly.

```
# vi ./config/common_base
        CONFIG_RTE_LIBRTE_PMD_QAT=y
# export RTE_SDK=/root/ipsec_demo/dpdk-17.02
# export RTE_TARGET=x86_64-native-linuxapp-gcc
# make install T=x86_64-native-linuxapp-gcc
```

Insert corresponding kernel modules when build process is successful.

```
# modprobe uio
# insmod ./x86_64-native-linuxapp-gcc/kmod/igb_uio.ko
```

Finally, make a soft link to /root/ipsec_demo for easy usage. This python script will be used later.

```
# ln -sf `pwd`/usertools/dpdk-devbind.py /root/ipsec_demo
```

For more detail, please refer to document from DPDK.org @

http://dpdk.org/doc/guides/linux_gsg/build_dpdk.html

1.5 Build IPsec Security Gateway Sample Application

Given Section 2.3 is done.

```
# cd  /root/ipsec_demo/dpdk-17.02
# make -C examples/ipsec-secgw
```

Make a soft link to /root/ipsec_demo for easy usage.

```
# ln -sf `pwd`/examples/ipsec-secgw/build/ipsec-secgw /root/ipsec_demo
```

1.6 Build DPDK Pktgen Application

The latest major version is 3.1.2 as of writing this. Given Section 2.3 is done.

```
# cd  /root/ipsec_demo
# tar xzf pktgen-dpdk-pktgen-3.1.2.tar.gz
# cd pktgen-dpdk-pktgen-3.1.2
# make
```

Make a soft link to /root/ipsec_demo for easy usage.

```
// For pktgen main binary
# ln -sf `pwd`/app/app/x86_64-native-linuxapp-gcc/pktgen /root/ipsec_demo
// Make a soft link to target folder as running binary "pktgen" requires this file at the same
directory.
# ln -sf `pwd`/Pktgen.lua /root/ipsec_demo
```

1.7 Build QAT driver

To use the DPDK QAT PMD an SRIOV-enabled QAT kernel driver is required. The VF devices exposed by this driver will be used by the QAT PMD. The devices and available kernel drivers and device ids are listed below :

Device	Driver	Kernel Module	Pci Driver	PF Did	Num PFs	VF Did	VFs per PF
DH895xCC	01.org	icp_qa_al	n/a	435	1	443	32
DH895xCC	4.4+	qat_dh895xcc	dh895xcc	435	1	443	32

The "Driver" column indicates either the Linux kernel version in which support for this device was introduced or a driver available on Intel's 01.org website. For the external QAT card with device DH895xCC, the kernel version for demonstration platform is shown below:

```
# uname -r
3.10.0-514.el7.x86_64
```

Apparently, an extra effort for installing driver from 01.org is required. Ensure that SRIOV is enabled and VT-d is disabled in the BIOS setting. Given the latest QuickAssist Technology Driver from 01.org is well-prepared at path /root/ipsec_demo. The latest major version is "qat1.2.6.0-60" as of writing this.

Ensure that any existing QAT driver are uninstalled.

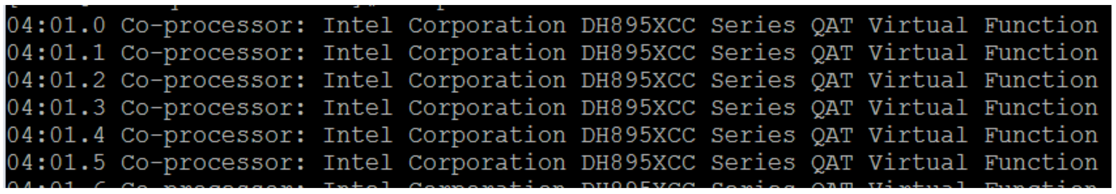
```
# rmmod qat_dh895xcc; rmmod intel_qat
```

Build and install the SRIOV-enabled QAT driver:

```
# cd  /root/ipsec_demo
# mkdir qatmux.l.2.6.0-60
# tar zxof qatmux.l.2.6.0-60.tgz -C qatmux.l.2.6.0-60
# cd qatmux.l.2.6.0-60
# export ICP_WITHOUT_IOMMU=1
# ./installer.sh install QAT1.6 host
```

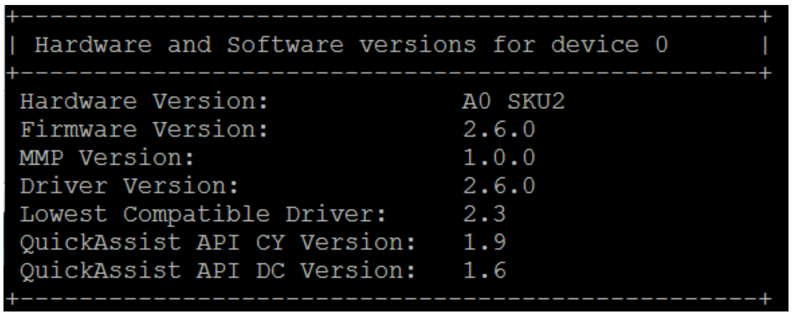
After above installation, the VFs can be checked by using below commands.

```
# lspci -d:443
```



```
04:01.0 Co-processor: Intel Corporation DH895XCC Series QAT Virtual Function
04:01.1 Co-processor: Intel Corporation DH895XCC Series QAT Virtual Function
04:01.2 Co-processor: Intel Corporation DH895XCC Series QAT Virtual Function
04:01.3 Co-processor: Intel Corporation DH895XCC Series QAT Virtual Function
04:01.4 Co-processor: Intel Corporation DH895XCC Series QAT Virtual Function
04:01.5 Co-processor: Intel Corporation DH895XCC Series QAT Virtual Function
```

```
# cat /proc/icp_dh895xcc_dev0/version
```



```
+--------------------------------------------------+
| Hardware and Software versions for device 0      |
+--------------------------------------------------+
 Hardware Version:             A0 SKU2
 Firmware Version:             2.6.0
 MMP Version:                  1.0.0
 Driver Version:               2.6.0
 Lowest Compatible Driver:     2.3
 QuickAssist API CY Version:   1.9
 QuickAssist API DC Version:   1.6
+--------------------------------------------------+
```

Totally 32 VF devices per QAT endpoint are available and the version can display which implies that the driver is correctly installed.

For more installation about other kernel or other QAT devices , please refer to document from DPDK.org @

http://dpdk.org/doc/guides/cryptodevs/qat.html

2. Demonstration Under the Platform

DPDK is a set of data plan libraries and optimized network interface drivers for fast packet processing. It provides a programming framework for Intel x86 processors and enables faster development of high speed data packet networking applications. The DPDK framework creates a set of libraries for specific hardware/software environments through the creation of an Environment Abstraction Layer (EAL). The EAL hides the environment specific and provides a standard interface to libraries, available hardware accelerators and other hardware and operating system elements. On top of ELA, developers link to the library to create their applications.

We will not explain too much DPDK technical details here. For more introductions to DPDK and DPDK documentation, please visit the following websites:

http://dpdk.org/

http://dpdk.readthedocs.io/en/v17.02/

2.1 lscpu

Before using DPDK, you need to understand the platform CPU architecture first. The command 'lscpu' gathers CPU info like number of CPUs, threads, cores, sockets, NUMA nodes, CPU caches, CPU family, model, byte order and stepping from sysfs and /proc/cpuinfo, and then prints out in a human-readable format.

Use the 'lscpu' command to dump CPU info:

```
[root@5020 ipsec_demo]# lscpu
Architecture:        x86_64
CPU op-mode(s):      32-bit, 64-bit
Byte Order:          Little Endian
CPU(s):              56
On-line CPU(s) list: 0-55
Thread(s) per core:  2
Core(s) per socket:  14
Socket(s):           2
NUMA node(s):        2
Vendor ID:           GenuineIntel
CPU family:          6
Model:               79
Model name:          Intel(R) Xeon(R) CPU E5-2680 v4@ 2.40GHz
Stepping:            1
CPU MHz:             1473.000
```

```
BogoMIPS:           4805.87
Virtualization:     VT-x
L1d cache:          32K
L1i cache:          32K
L2 cache:           256K
L3 cache:           35840K
NUMA node0 CPU(s):    0-13,28-41
NUMA node1 CPU(s):    14-27,42-55
```

Our example platform (FWA-5020U-D0A1R) has 2 CPU sockets, 14 cores per socket and 2 threads per core. As such, there are total 56 (socket*cores*threads) logical CPUs to the operating system (OS). Where logical CPU core ID 0 to 13, 28 to 41 are belongs to NUMA node0, while logical CPU core ID 14 to 27, 42 to 55 are as the other NUMA node (node1).

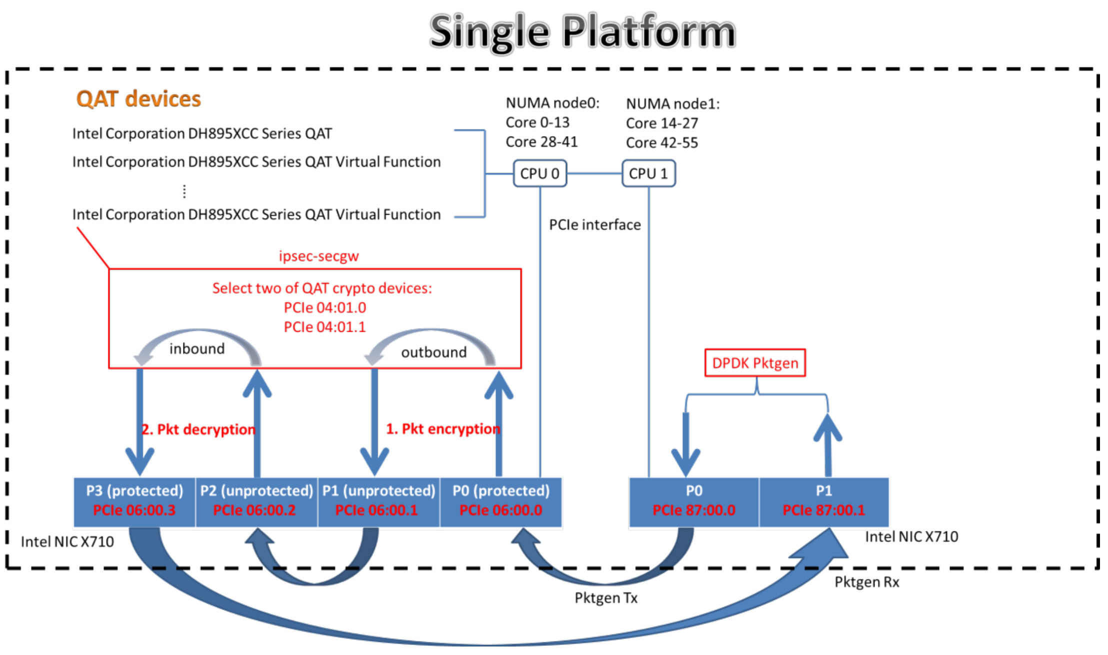

Single Platform
QAT devices
Intel Corporation DH895XCC Series QAT
Intel Corporation DH895XCC Series QAT Virtual Function
Intel Corporation DH895XCC Series QAT Virtual Function
NUMA node0: Core 0-13 Core 28-41
NUMA node1: Core 14-27 Core 42-55
CPU 0
CPU 1
PCIe interface
ipsec-secgw
Select two of QAT crypto devices: PCIe 04:01.0 PCIe 04:01.1
inbound
outbound
2. Pkt decryption
1. Pkt encryption
DPDK Pktgen
P3 (protected) PCIe 06:00.3
P2 (unprotected) PCIe 06:00.2
P1 (unprotected) PCIe 06:00.1
P0 (protected) PCIe 06:00.0
P0 PCIe 87:00.0
P1 PCIe 87:00.1
Intel NIC X710
Intel NIC X710
Pktgen Tx
Pktgen Rx

Fig8: Relationship between NIC PFA and CPU NUMA node

Considering the scenario described before, it’s suggested that the NIC ports are bound to the same CPU NUMA node within DPDK engine where its PCI Function Address (PFA) belongs to. In the demonstration, NIC port with PFA 87:00.0 and 87:00.1 will be bound to CPU NUMA node 1, while PFA 06:00.0~06:00.3, 04:01.0~04:01.1 will be bound to CPU NUMA node0.

2.2 Intel DPDK pktgen

The Pktget application is a software based traffic generator powered by the DPDK fast packet processing framework and is used for sourcing and sinking network traffic.

2.2.1 Command Usage of Pktgen

Pktgen splits its command line arguments into arguments for the EAL and arguments for the application itself. The first group is a list of EAL options that are common to all DPDK based applications. The second group of options are application specific. The two sets of arguments are separated using the standard convention of -- as shown below.

```
# pktgen [EAL options] -- [Application options]
```

Here is the usage of EAL and application arguments which are used in our examples:

- EAL options:
  - --master-lcore <ID>: Core ID that is used as master. Note that the master core should not be used for handing Tx or Rx packets transmission
  - -c <COREMASK>: a hexadecimal bitmask of the cores to run on
  - -n <CHANNELS>: number of memory channels
  - -w, --pci-whitelist: Add a PCI device in white list. Only use the specified PCI devices. The argument format is <[domain:]bus:devid.func>. This option can be present several times (once per device).
  - --socket-mem: memory to allocate on specific sockets (use comma separated values)
  - --file-prefix: prefix for hugepage filenames.
- Application options:
  - -T: enable the color output
  - -m <string>: Matrix for mapping ports to logical cores. The format of the port mapping string is defined with a BNF-like grammar. For example,
    - "[rx_core:tx_core].port1_num,[rx_core:tx_core.port2_num" refers to which cores will be used for port1 and port2 tx/rx transmission. See http://pktgen.readthedocs.io/en/latest/usage_pktgen.html#usage-pktgen for more details.
  - -P: Enable PROMISCUOUS mode on all ports. Sets all ports to promiscuous mode so that packets are accepted regardless of the packet's Ethernet MAC destination address. Without this option, only packets with the Ethernet MAC destination address set to the Ethernet address of the port are accepted (default is enabled).

More complete usage can be found in http://pktgen.readthedocs.io/en/latest/running.html.

2.2.2 Running Pktgen

Step 1: Given that kernel module and DPDK poll mode drivers are well-loaded

```
# modprobe uio
# cd /root/ipsec_demo
# insmod ./dpdk-17.02/x86_64-native-linuxapp-gcc/kmod/igb_uio.ko
```

Step 2: Setting the number of huge pages reserved for each CPU node. Default 1024 pages is selected for NUMA node 0 and so does NUMA node 1. As each huge page is 2MB (2048kB), in total 2GB (2MB*1024) huge page per NUMA node is reserved for DPDK usage.

```
# echo 1024 > /sys/devices/system/node/node0/hugepages/hugepages-
2048kB/nr_hugepages
# echo 1024 > /sys/devices/system/node/node1/hugepages/hugepages-
2048kB/nr_hugepages
```

Step 3: Creating /mnt/huge directory and mounting it as hugetlbfs

```
# mkdir -p /mnt/huge
# mount -t hugetlbfs nodev /mnt/huge
```

Step 4: Make sure huge page is mounted already

```
# grep '/mnt/huge' /proc/mounts
nodev /mnt/huge hugetlbfs rw,relatime 0 0
```

Step 5: Let the NIC ports which involve in the demonstration be managed by DPDK PMD engine. Total six ports with PFA 87:00.0~87:00.1, 06:00.0~06:00.3

```
# ip link set b87p0 down
# ip link set b87p1 down
# ip link set b06p0 down
# ip link set b06p1 down
# ip link set b06p2 down
# ip link set b06p3 down
# ./dpdk-devbind.py -b igb_uio b87p0 b87p1 b06p0 b06p1 b06p2 b06p3
```

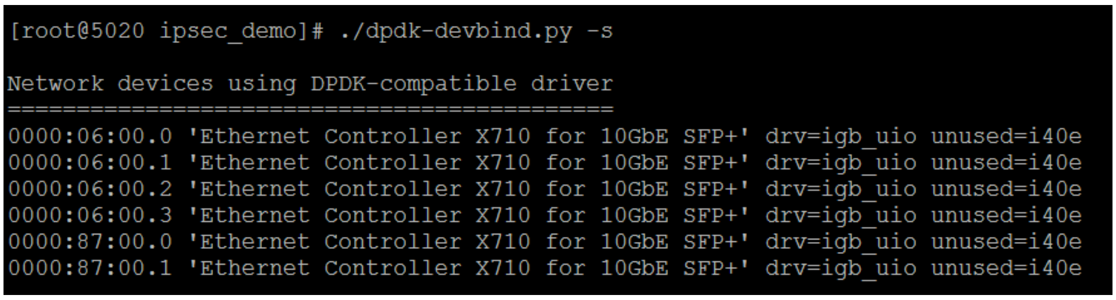
Step 6: Configure the QAT VF ports which will be managed by DPDK

```
# ./dpdk-devbind.py -b igb_uio 04:01.0 04:01.1
```

The dpdk-devbind.py is a python script which is used by network device and crypto device driver to bind corresponding port to DPDK PMD. The parameter '-b' indicates which driver is bound to following devices. In our example, the 6 NIC drivers and 2 QAT VF crypto device drivers are bound to DPDK PMD.

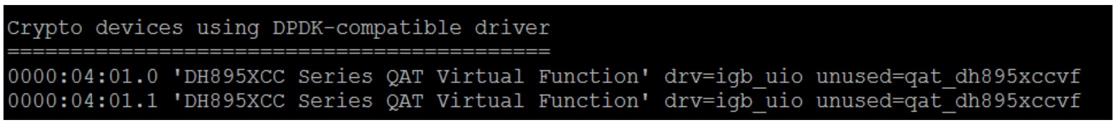
Use the command '*dpdk-devbind.py --status*' to check whether they had been managed by DPDK PMD correctly:

```
# ./dpdk-devbind.py -s
```



```
[root@5020 ipsec_demo]# ./dpdk-devbind.py -s

Network devices using DPDK-compatible driver
============================================
0000:06:00.0 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
0000:06:00.1 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
0000:06:00.2 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
0000:06:00.3 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
0000:87:00.0 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
0000:87:00.1 'Ethernet Controller X710 for 10GbE SFP+' drv=igb_uio unused=i40e
```



```
Crypto devices using DPDK-compatible driver
===========================================
0000:04:01.0 'DH895XCC Series QAT Virtual Function' drv=igb_uio unused=qat_dh895xccvf
0000:04:01.1 'DH895XCC Series QAT Virtual Function' drv=igb_uio unused=qat_dh895xccvf
```

Use the 'dpdk-devbind.py --help' command to get more detailed usage.

Step 7: Start Pktgen Program

```
./pktgen --master-lcore 18 -c 007c000 -n 16  -w 87:00.0 -w 87:00.1 --socket-mem=1,512 --
file-prefix=dpdk_pktgen  -- -P -T -m '[14:15].0,[16:17].1'
```

Parameters setting:

- *--master-lcore 18*

The 19th logical CPU core (CPU ID 18) in NUMA node1 is selected for running Pktgen master process.

- *-c* 007c000

CPU cores ID 14 and ID 15 are dedicated for Rx and Tx on Port 0 (b87p0, PFA 87:00.0) respectively. CPU cores ID 16 and ID 17 are dedicated for Rx and Tx on Port 1 (b87p1, PFA 87:00.1) respectively. Thus CPU core ID 18 is used by Pktgen master process.

- *-n 16*

memory channels = 16

- *-w 87:00.0 -w 87:00.1*

set white list of PFA of b87p0 and b87p1.

- *--socket-mem=1,512*

The huge page was assigned as 4096MB in Step 2. Allocate 512MB for CPU socket 1 for Pktgen program since the bound cores are located in CPU NUMA node 1, and allocate 1 MB for CPU socket 0. Here is an unknown issue that memory cannot allocate 0MB to CPU socket 0 in this DPDK Pktgen version (3.1.2) eventhough Pktgen won't use any cores in CPU NUMA node 0.

- *--file-prefix=dpdk_pktgen*

As the programs of DPDK Pktgen and ipsec-secgw use the same DPDK engine, thus we need to assign a prefix label to make DPDK engine to differentiate them.

- *-m '[14:15].0,[16:17].1*

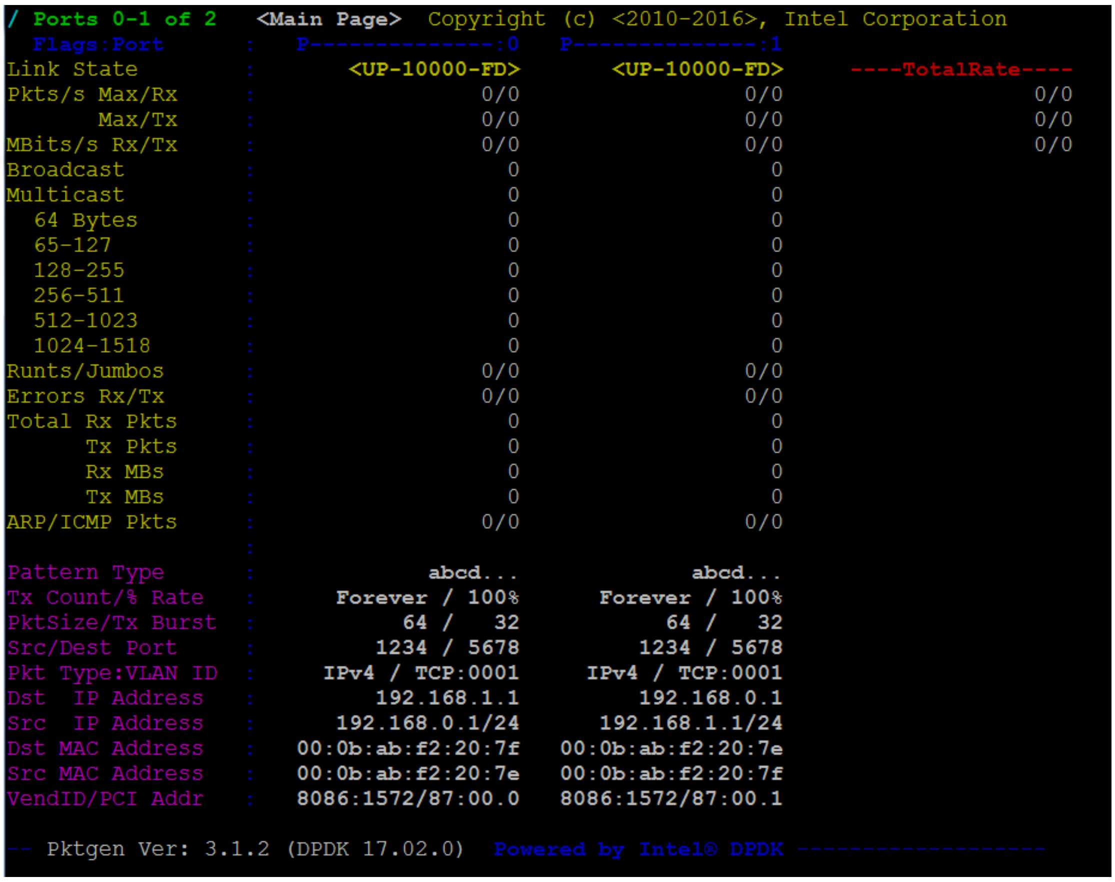
The logical CPU core (ID 14) handles port 0 RX

The logical CPU core (ID 15) handles port 0 TX

The logical CPU core (ID 2) handles port 1 RX

The logical CPU core (ID 3) handles port 1 TX

If running successfully, user shall end up with Pktgen CLI:



```
/ Ports 0-1 of 2   <Main Page>  Copyright (c) <2010-2016>, Intel Corporation
  Flags:Port      :   P--------------:0   P--------------:1
Link State        :       <UP-10000-FD>       <UP-10000-FD>     ----TotalRate----
Pkts/s Max/Rx     :                 0/0                 0/0                   0/0
       Max/Tx     :                 0/0                 0/0                   0/0
MBits/s Rx/Tx     :                 0/0                 0/0                   0/0
Broadcast         :                   0                   0
Multicast         :                   0                   0
  64 Bytes        :                   0                   0
  65-127          :                   0                   0
  128-255         :                   0                   0
  256-511         :                   0                   0
  512-1023        :                   0                   0
  1024-1518       :                   0                   0
Runts/Jumbos      :                 0/0                 0/0
Errors Rx/Tx      :                 0/0                 0/0
Total Rx Pkts     :                   0                   0
      Tx Pkts     :                   0                   0
      Rx MBs      :                   0                   0
      Tx MBs      :                   0                   0
ARP/ICMP Pkts     :                 0/0                 0/0
                  :
Pattern Type      :             abcd...             abcd...
Tx Count/% Rate   :      Forever / 100%      Forever / 100%
PktSize/Tx Burst  :           64 /   32           64 /   32
Src/Dest Port     :         1234 / 5678         1234 / 5678
Pkt Type:VLAN ID  :     IPv4 / TCP:0001     IPv4 / TCP:0001
Dst  IP Address   :         192.168.1.1         192.168.0.1
Src  IP Address   :      192.168.0.1/24      192.168.1.1/24
Dst MAC Address   :   00:0b:ab:f2:20:7f   00:0b:ab:f2:20:7e
Src MAC Address   :   00:0b:ab:f2:20:7e   00:0b:ab:f2:20:7f
VendID/PCI Addr   :   8086:1572/87:00.0   8086:1572/87:00.1

-- Pktgen Ver: 3.1.2 (DPDK 17.02.0)  Powered by Intel® DPDK -------------------
```

Fig9: Snapshot of Pktgen program starts

Type *'help'* in CLI to get complete Pktgen CLI usage and type 'exit' to close.

2.3 Intel DPDK IPSec Gateway

The IPsec Security Gateway application is an example of a “real world” application using DPDK cryptodev framework. The application demonstrates the implementation of a Security Gateway (not IPsec compliant) using DPDK based on RFC4301, RFC4303, RFC3602 and RFC2404. The traffic is classified as inbound traffic and outbound traffic which is already described in Section 2.1.

The Path for the IPsec outbound traffic is:

1. Read packets from the port.
2. Perform outbound Security Policy (SP) check using Access Control List (ACL) of all IPv4 traffic.
3. Perform outbound Security Associations (SA) lookup for packets that need IPsec protection.
4. Add Encapsulating Security Payload (ESP) and outer IP header.
5. Perform Encryption/Digest.
6. Routing.
7. Write packet to port.

The Path for IPsec inbound traffic is:

1. Read packets from the port.
2. Classify packets between IPv4 and ESP.
3. Perform inbound SA lookup for ESP packets based on their Security Parameter Index (SPI).
4. Perform Verification/Decryption.
5. Remove ESP and outer IP header
6. Inbound SP check using ACL of decrypted packets and any other IPv4 packets.
7. Routing.
8. Write packet to port.

2.3.1 Command Usage of ipsec-secgw

The application ipsec-secgw usage is similar to Pktgen.

```
# ipsec-secgw [EAL options] --
                 -p PORTMASK -P -u PORTMASK
                --config (port,queue,lcore)[,(port,queue,lcore]
                --single-sa SAIDX
                -f CONFIG_FILE_PATH
```

Where:

- EAL options:
  - --master-lcore <ID>: Core ID that is used as master.
  - -c <COREMASK>: a hexadecimal bitmask of the cores to run on
  - -l <CORELIST>: List of cores to run on
  - -n <CHANNELS>: number of memory channels
  - -w, --pci-whitelist: Add a PCI device in white list. Only use the specified PCI devices. The argument format is <[domain:]bus:devid.func>. This option can be present several times (once per device).
  - --socket-mem: memory to allocate on specific sockets (use comma separated values)
  - --file-prefix: prefix for hugepage filenames.
- Application options:
  - -p <PORTMASK>: Hexadecimal bitmask of ports to configure.
  - -P: Sets all ports to promiscuous mode so that packets are accepted regardless of the packet’s Ethernet MAC destination address. Without this option, only packets with the Ethernet MAC destination address set to the Ethernet address of the port are accepted (default is enabled).
  - -u <PORTMASK>: hexadecimal bitmask of unprotected ports
  - --config (port,queue,lcore)[,(port,queue,lcore)]: determines which queues from which ports are mapped to which cores. For example,
  - --single-sa <SAIDX>: use a single SA for outbound traffic, bypassing the SP on both Inbound and Outbound. This option is meant for debugging/performance purposes.
  - -f <CONFIG_FILE_PATH>: the full path of text-based file containing all configuration items for running the application (See Configuration File Syntax section below). -f <CONFIG_FILE_PATH> must be specified. ONLY the UNIX format configuration file is accepted.

The application would do a best effort to “map” crypto devices to cores, with hardware devices having priority. Hardware devices if present would be assigned to a core before software ones. A way to achieve the case where the virtual crypto devices were forced to use is to whitelist the devices needed and therefore implicitly blacklisting all other hardware crypto devices.

2.3.2 Configuration File Syntax

The following sections provide the syntax of configurations to initialize your SP, SA and Routing tables. Configurations shall be specified in the configuration file to be passed to the application. The file is then parsed by the application. The successful parsing will result in the appropriate rules being applied to the tables accordingly.

2.3.2.1 General Rule Syntax

The parse treats one line in the configuration file as one configuration item (unless the line concatenation symbol exists). Every configuration item shall follow the syntax of either SP, SA, or Routing rules specified below.

The configuration parser supports the following special symbols:

- Comment symbol #. Any character from this symbol to the end of line is treated as comment and will not be parsed.
- Line concatenation symbol \. This symbol shall be placed in the end of the line to be concatenated to the line below. Multiple lines’ concatenation is supported.

2.3.2.2 SP Rule Syntax

The SP rule syntax is shown as follows:

```
sp <ip_ver> <dir> esp <action> <priority> <src_ip> <dst_ip> <proto> <sport> <dport>
```

where each options means:

- <ip_ver>: IP protocol version
  - Optional: No
  - Avaliable options:
    - ipv4: IP protocol version 4
    - ipv6: IP protocol version 6
- <dir>: The traffic direction
  - Optional: No
  - Avaliable options:
    - in: inbound traffic
    - out: outbound traffic

- <action>: IPsec action
  - Optional: No
  - Available options:
    - protect <SA_idx>: the specified traffic is protected by SA rule with id SA_idx. Note that the SA_idx would become SA's SPI number. Please refer to below link for more detail: https://en.wikipedia.org/wiki/Security_Parameter_Index
    - bypass: the specified traffic traffic is bypassed
    - discard: the specified traffic is discarded
- <priority>: Rule priority
  - Optional: Yes, default priority 0 will be used
  - Syntax: pri <id>
- <src_ip>: The source IP address and mask
  - Optional: Yes, default address 0.0.0.0 and mask of 0 will be used
  - Syntax:
    - src X.X.X.X/Y for IPv4
    - src XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX/Y for IPv6
- <dst_ip>: The destination IP address and mask
  - The destination IP address and mask
  - Syntax:
    - dst X.X.X.X/Y for IPv4
    - dst XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX/Y for IPv6
- <proto>: The protocol start and end range
  - Optional: yes, default range of 0 to 0 will be used
  - Syntax: proto X:Y
- <sport>: The source port start and end range
  - Optional: yes, default range of 0 to 0 will be used
  - Syntax: sport X:Y
- <dport>: The destination port start and end range
  - Optional: yes, default range of 0 to 0 will be used
  - Syntax: dport X:Y

Currently, sport and dport option found an unknow issue that only 0:65535 is workable for now. Anyway, it doen't affect our demonstration.

2.3.2.3 SA Rule Syntax

The SA rule syntax is shown as follows:

```
sa <dir> <spi> <cipher_algo> <cipher_key> <auth_algo> <auth_key> <mode> <src_ip>
<dst_ip>
```

where each options means:

- <dir>: The traffic direction
  - Optional: No
  - Available options:
    - in: inbound traffic
    - out: outbound traffic
- <spi>: The SPI number
  - Optional: No
  - Syntax: unsigned integer number
- <cipher_algo>: Cipher algorithm
  - Optional: No
  - Available options:
    - Please refer to below link to find supported Cipher Algorithms http://dpdk.org/doc/guides/cryptodevs/overview.html
  - Syntax: cipher_algo <your algorithm>
- <cipher_key>: Cipher key, NOT available when 'null' algorithm is used
  - Optional: No, must followed by <cipher_algo> option
  - Syntax: Hexadecimal bytes (0x0-0xFF) concatenate by colon symbol ':'. The number of bytes should be as same as the specified cipher algorithm key size.
    - For example: cipher_key A1:B2:C3:D4:A1:B2:C3:D4:A1:B2:C3:D4:A1:B2:C3:D4
- <auth_algo>: Authentication algorithm
  - Optional: No
  - Available options:
    - Please refer to below link to find supported Cipher Algorithms http://dpdk.org/doc/guides/cryptodevs/overview.html
  - Syntax: auth_algo <your algorithm>

- <auth_key>: Authentication key, NOT available when 'null' or 'aes-128-gcm' algorithm is used.
    - Optional: No, must followed by <auth_algo> option
    - Syntax: Hexadecimal bytes (0x0-0xFF) concatenate by colon symbol ':'. The number of bytes should be as same as the specified authentication algorithm key size.
        - For example: auth_key A1:B2:C3:D4:A1:B2:C3:D4:A1:B2:C3:D4:A1:B2:C3:D4: A1:B2:C3:D4
- <mode>: The operation mode
    - Optional: No
    - Available options:
        - ipv4-tunnel: Tunnel mode for IPv4 packets
        - ipv6-tunnel: Tunnel mode for IPv6 packets
        - transport: transport mode
    - Syntax: mode XXX
- <src_ip>: The source IP address. This option is not available when transport mode is used
    - Optional: Yes, default address 0.0.0.0 will be used
    - Syntax:
        - src X.X.X.X for IPv4
        - src XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX for IPv6
- <dst_ip>: The destination IP address. This option is not available when transport mode is used
    - Optional: Yes, default address 0.0.0.0 will be used
    - Syntax:
        - dst X.X.X.X for IPv4
        - dst XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX for IPv6

2.3.2.4 Routing Rules Syntax

The Routing rule syntax is shown as follows:

```
rt <ip_ver> <src_ip> <dst_ip> <port>
```

where each options means:

- <ip_ver>: IP protocol version
  - Optional: No
  - Available options:
    - ipv4: IP protocol version 4
    - ipv6: IP protocol version 6
- <src_ip>: The source IP address and mask
  - Optional: Yes, default address 0.0.0.0 and mask of 0 will be used
  - Syntax:
    - src X.X.X.X/Y for IPv4
    - src XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX/Y for IPv6
- <dst_ip>: The destination IP address and mask
  - Optional: Yes, default address 0.0.0.0 and mask of 0 will be used
  - Syntax:
    - dst X.X.X.X/Y for IPv4
    - dst XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX/Y for IPv6
- <port>: The traffic output port id
  - Optional: yes, default output port 0 will be used
  - Syntax: port X

2.3.3 Running ipsec-secgw

Before running ipsec-secgw program, we need to deploy our configuration firstly, which is already described in previous section. Remind the concept of inbound and outbound traffic, at least two endpoints (EP) are needed, one for ciphering, one for deciphering. And the ciphered content transmitted in the media by tunnenling protocol.

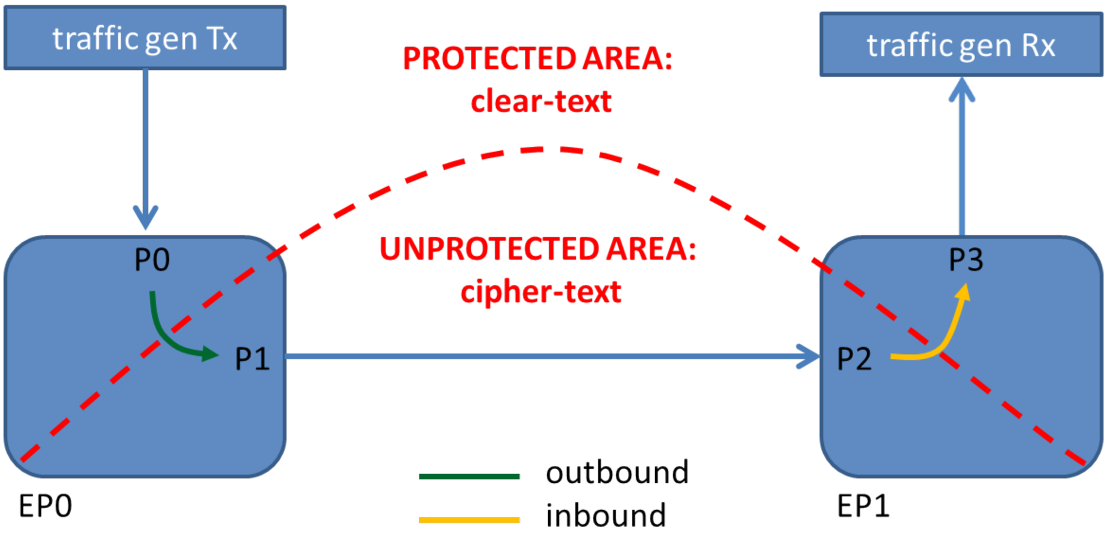


Fig10: Protected area and unprotected area

As a result, the security policy of each EPs for the demonstration are summarized in following tables.

- Endpoint 0 outbound traffic:

  1. Security Policy:

Src	Dest	SA Index
Any	192.168.1.0/24 (Pkgen default setting)	5

The SA index is an arbitrary unsigned integer, which maps to the SPI number of SA. Here, a digit 5 is choosen. After all ciphering/authentication algorithms done, route the packets to port 1 with headers for tunnelling. And the IPs of ESP becomes to tunnelling IPs that we assigned. Please see below.

  2. Security Associations:

SPI	Cipher	Auth	Tunnel Src	Tunnel Dest
5	aes-128-cbc	sha1-hmac	172.16.1.5	172.17.2.5

The supported algorithms can refer to the following website @ http://dpdk.org/doc/guides/cryptodevs/overview.html

Because we use QAT driver for crypto devices, the supported functionality matrices differ with others.

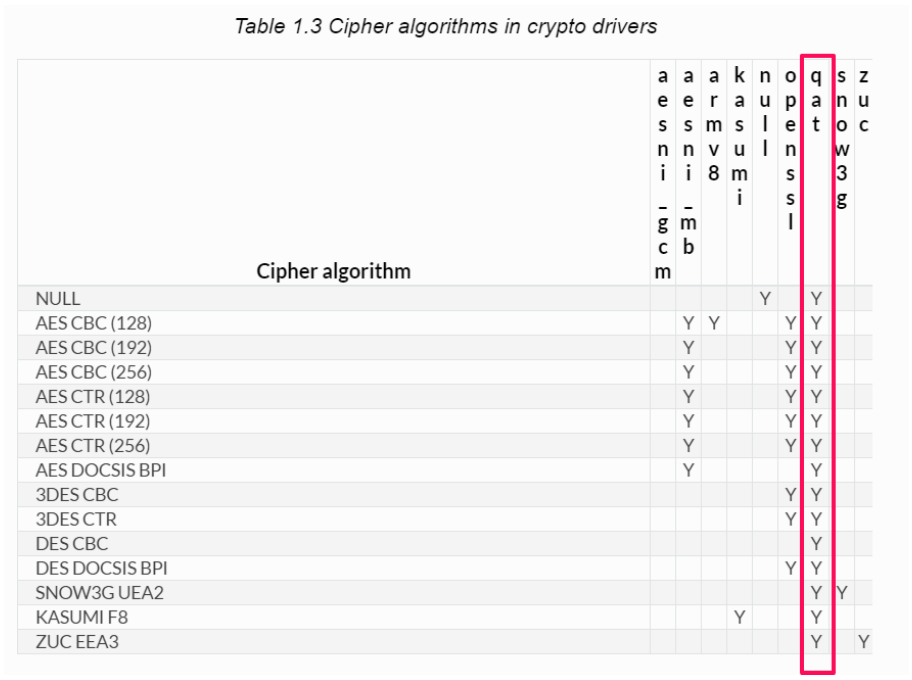


Table 1.3 Cipher algorithms in crypto drivers

Cipher algorithm	aesni_gcm	aesni_mb	armv8	kasumi	null	openssl	qat	snow3g	zuc
NULL					Y		Y		
AES CBC (128)		Y	Y			Y	Y		
AES CBC (192)		Y				Y	Y		
AES CBC (256)		Y				Y	Y		
AES CTR (128)		Y				Y	Y		
AES CTR (192)		Y				Y	Y		
AES CTR (256)		Y				Y	Y		
AES DOCSIS BPI		Y					Y		
3DES CBC						Y	Y		
3DES CTR						Y	Y		
DES CBC							Y		
DES DOCSIS BPI						Y	Y		
SNOW3G UEA2							Y	Y	
KASUMI F8				Y			Y		
ZUC EEA3							Y		Y

Fig 11: Supported Cipher Algorithms

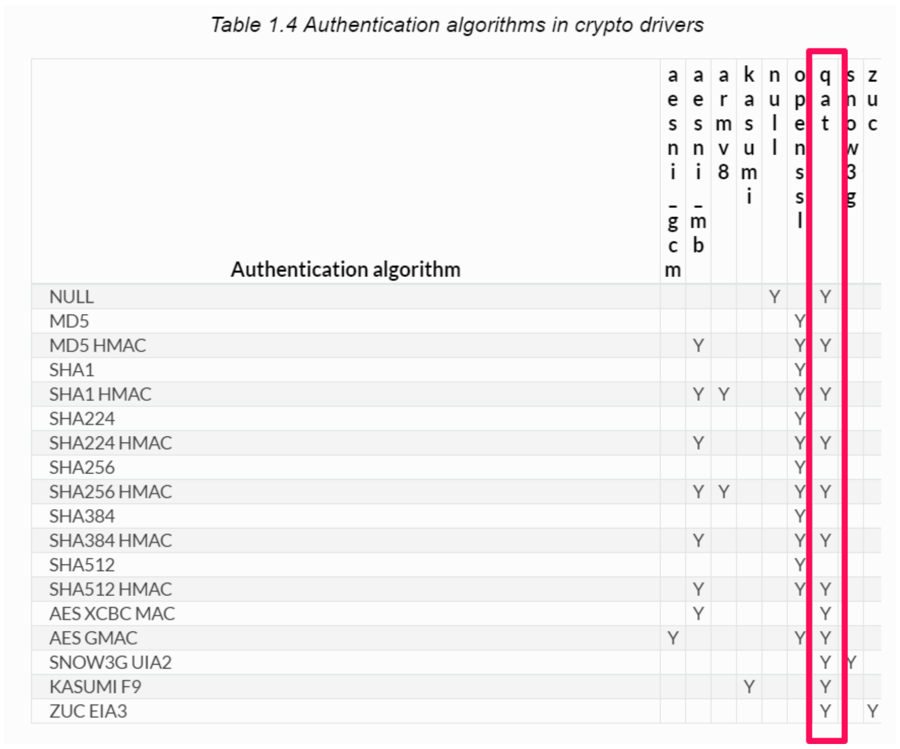


Table 1.4 Authentication algorithms in crypto drivers

Authentication algorithm	aesni_gcm	aesni_mb	armv8	kasumi	null	openssl	qat	snow3g	zuc
NULL					Y		Y		
MD5						Y			
MD5 HMAC		Y				Y	Y		
SHA1						Y			
SHA1 HMAC		Y	Y			Y	Y		
SHA224						Y			
SHA224 HMAC		Y				Y	Y		
SHA256						Y			
SHA256 HMAC		Y	Y			Y	Y		
SHA384						Y			
SHA384 HMAC		Y				Y	Y		
SHA512						Y			
SHA512 HMAC		Y				Y	Y		
AES XCBC MAC		Y					Y		
AES GMAC	Y					Y	Y		
SNOW3G UIA2							Y	Y	
KASUMI F9				Y			Y		
ZUC EIA3							Y		Y

Fig 12: Supported Authentication Algorithms

3. Routing : port 1

- Endpoint 1 inbound traffic:

  1. Security Policy:

Src	Dest	SA Index
Any	192.168.1.0/24 (Pkgen default setting)	5

Note that the SA Index should be the same as what outbound traffic set. It's because ESP header contains the SPI information. After all deciphering/authentication algorithms done, route the packets to port 3 with headers for tunnelling out. And the payload content is assumed safe now.

  2. Security Associations:

SPI	Cipher	Auth	Tunnel Src	Tunnel Dest
5	aes-128-cbc	sha1-hmac	172.16.1.5	172.17.2.5

  3. Routing : port 3

Step 1: Prepare config file for ipsec-secgw program

```
# cd /root/ipsec_demo

# vim ipsec_secgw_rules.cfg

# usage of SP rule syntax: sp <ip_ver> <dir> esp <action> <priority> <src_ip> <dst_ip>
<proto> <sport> <dport>

# usage of SA rule syntax: sa <dir> <spi> <cipher_algo> <cipher_key> <auth_algo>
<auth_key> <mode> <src_ip> <dst_ip>

# usage of routing rule syntax: rt <ip_ver> <src_ip> <dst_ip> <port>


# First endpoint (End point 0) outbound:

# Security Policy

sp ipv4 out esp protect 5 dst 192.168.1.0/24 sport 0:65535 dport 0:65535


# Security Associations

sa out 5 \

cipher_algo aes-128-cbc \

cipher_key c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3 \

auth_algo sha1-hmac \

auth_key 0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0 \

mode ipv4-tunnel \
src 172.16.1.5 \
dst 172.17.2.5

# Routing
rt ipv4 dst 172.17.2.5/32 port 1

# Second endpoint (End point 1) inbound:
sp ipv4 in esp protect 5 dst 192.168.1.0/24 sport 0:65535 dport 0:65535

sa in 5 \
cipher_algo aes-128-cbc \
cipher_key c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3:c3 \
auth_algo sha1-hmac \
auth_key 0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0 \
mode ipv4-tunnel \
src 172.16.1.5 \
dst 172.17.2.5

# Routing
rt ipv4 dst 192.168.1.0/24 port 3
```

Step 2: Given that Pktgen in section 2.2.2 is prepared ready (with CLI environment).

Step 3: Create another login window (SSH is recommended) to start ipsec-secgw program

```
# ./ipsec-secgw --master-lcore 1 -l 1,2,3,4 -n 16 --socket-mem=512,0 --file-prefix=qat -w
06:00.0 -w 06:00.1 -w 06:00.2 -w 06:00.3 -w 04:01.0 -w 04:01.1  -- -p 0xf -P -u 0x06 --
config="(0,0,1),(1,0,2),(2,0,3),(3,0,4)" -f ./ipsec_secgw_rules.cfg
```

Parameters setting:

- *--master-lcore 1*

The 2nd logical CPU core (CPU ID 1) in NUMA node0 is selected for running ipsec-secgw master process.

- -l 1,2,3,4

CPU cores ID 1-4 are dedicated for the ipsec-secgw program, and how they are bound to NIC ports will be assigned within parameter "--config".

- *-n 16*

memory channels = 16

- -w 06:00.0 -w 06:00.1 -w 06:00.2 -w 06:00.3 -w 04:01.0 -w 04:01.1

set white list of PFA of 4 ports NIC (PFA 06:00.0~06:00.3) and 2 QAT VFs (PFA 04:01.0~04:01.1).

- *--socket-mem=512,0*

The huge page was assigned as 4096MB for DPDK PMD. Allocate 512MB for CPU socket 0 for ipsec-secgw program since the bound cores are located in CPU NUMA node 0.

- *--file-prefix=qat*

As the programs of DPDK Pktgen and ipsec-secgw use the same DPDK engine, thus we need to assign a prefix label to make DPDK engine to differentiate them.

- -p 0xf

The configuration will apply to four ports, called port 0 (PFA 06:00.0) to port 3 (PFA 06:00.3) respectively.

- -u 0x06

Among four ports, two of them are tagged as unprotected ports, while the other two ports are regarded as protected ports. According to port classification, the traffic type as inbound or outbound can be defined thereafter. In our demonstration, port 1 and port 2 are unprotected ports, thus we set mask as 0x06. Please refer to Fig 10.

- --config="(0,0,1),(1,0,2),(2,0,3),(3,0,4)"

Map queue 0 from port 0 to CPU lcore 1, and so on.

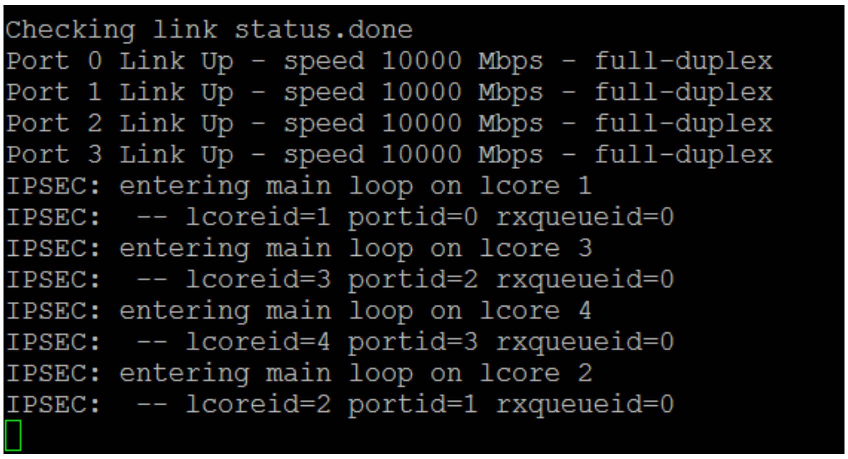
Port	Queue	lcore
0	0	1
1	0	2
2	0	3
3	0	4

Where lcore is defined by *-l <CORELIST>* or *-c <COREMASK>* parameter.

For other information in more detail, following website can be referred directly.

http://dpdk.org/doc/guides/sample_app_ug/ipsec_secgw.html

The ipsec-secgw running result:

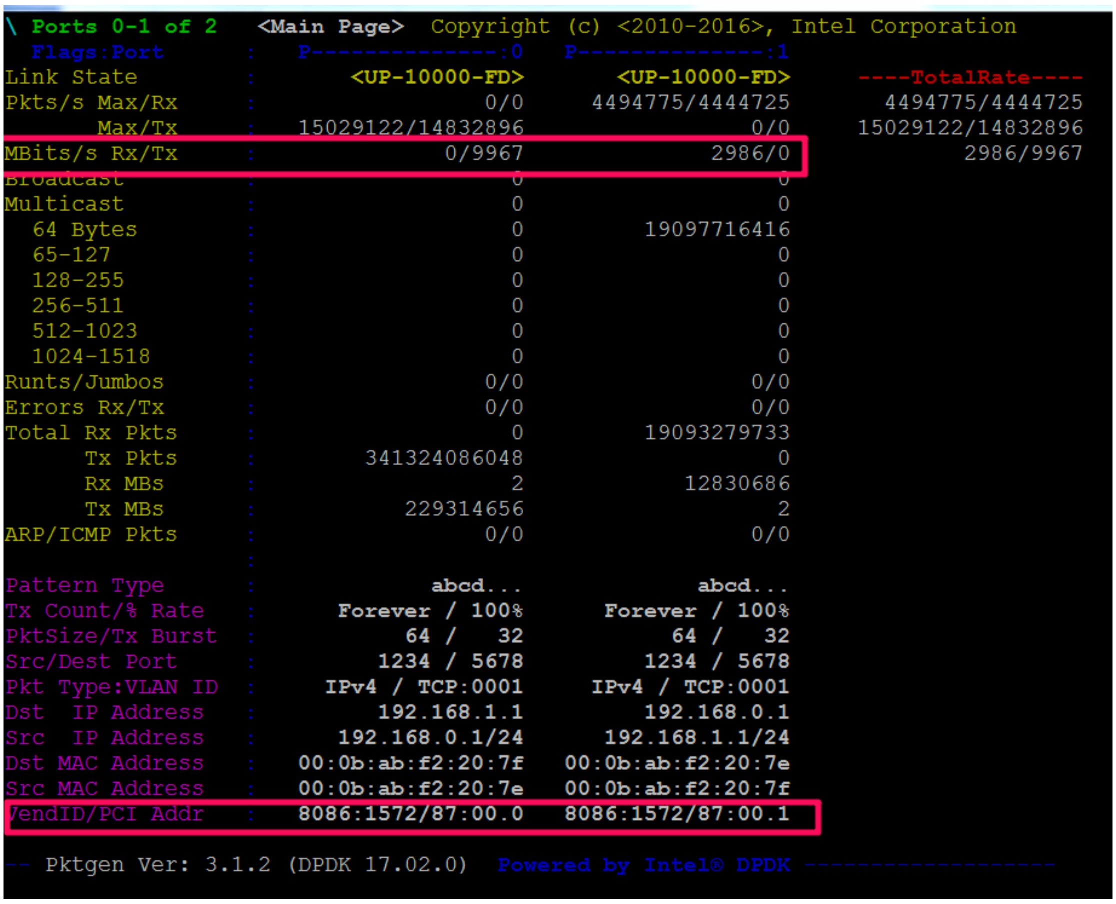


```
Checking link status.done
Port 0 Link Up - speed 10000 Mbps - full-duplex
Port 1 Link Up - speed 10000 Mbps - full-duplex
Port 2 Link Up - speed 10000 Mbps - full-duplex
Port 3 Link Up - speed 10000 Mbps - full-duplex
IPSEC: entering main loop on lcore 1
IPSEC:  -- lcoreid=1 portid=0 rxqueueid=0
IPSEC: entering main loop on lcore 3
IPSEC:  -- lcoreid=3 portid=2 rxqueueid=0
IPSEC: entering main loop on lcore 4
IPSEC:  -- lcoreid=4 portid=3 rxqueueid=0
IPSEC: entering main loop on lcore 2
IPSEC:  -- lcoreid=2 portid=1 rxqueueid=0
```

Step 4: Given DPDK pktgen is running. Text "start 0" to initiate packet transmit from PCF 87:00.0, and observe packet resceive from PCF 87:00.1

In Pktgen CLI:

Pktgen > start 0



```
\ Ports 0-1 of 2   <Main Page>  Copyright (c) <2010-2016>, Intel Corporation
  Flags:Port       :    P--------------:0   P--------------:1
Link State         :        <UP-10000-FD>       <UP-10000-FD>     ----TotalRate----
Pkts/s Max/Rx      :                  0/0     4494775/4444725       4494775/4444725
       Max/Tx      :    15029122/14832896                 0/0     15029122/14832896
MBits/s Rx/Tx      :               0/9967              2986/0             2986/9967
Broadcast          :                    0                   0
Multicast          :                    0                   0
  64 Bytes         :                    0         19097716416
  65-127           :                    0                   0
  128-255          :                    0                   0
  256-511          :                    0                   0
  512-1023         :                    0                   0
  1024-1518        :                    0                   0
Runts/Jumbos       :                  0/0                 0/0
Errors Rx/Tx       :                  0/0                 0/0
Total Rx Pkts      :                    0         19093279733
      Tx Pkts      :         341324086048                   0
      Rx MBs       :                    2            12830686
      Tx MBs       :            229314656                   2
ARP/ICMP Pkts      :                  0/0                 0/0
                   :
Pattern Type       :              abcd...             abcd...
Tx Count/% Rate    :       Forever / 100%      Forever / 100%
PktSize/Tx Burst   :            64 /   32           64 /   32
Src/Dest Port      :          1234 / 5678         1234 / 5678
Pkt Type:VLAN ID   :      IPv4 / TCP:0001     IPv4 / TCP:0001
Dst  IP Address    :          192.168.1.1         192.168.0.1
Src  IP Address    :       192.168.0.1/24      192.168.1.1/24
Dst MAC Address    :    00:0b:ab:f2:20:7f   00:0b:ab:f2:20:7e
Src MAC Address    :    00:0b:ab:f2:20:7e   00:0b:ab:f2:20:7f
VendID/PCI Addr    :    8086:1572/87:00.0   8086:1572/87:00.1

-- Pktgen Ver: 3.1.2 (DPDK 17.02.0)  Powered by Intel® DPDK -------------------
```

Step 5: In Pktgen CLI, type 'exit' to close Pktgen. In the window with ipsec-secgw program running, press 'Ctrl+c' to close ipsec-secgw program.

3. Reference

- DPDK org:
  - Getting Started Guide for Linux
    http://dpdk.org/doc/guides/linux_gsg/index.html
    - System Requirements
      http://dpdk.org/doc/guides/linux_gsg/sys_reqs.html
    - Compiling the DPDK Target from Source
      http://dpdk.org/doc/guides/linux_gsg/build_dpdk.html
  - Crypto Device Drivers
    http://dpdk.org/doc/guides/cryptodevs/index.html
    - Intel(R) QuickAssist (QAT) Crypto Poll Mode Driver
      http://dpdk.org/doc/guides/cryptodevs/qat.html
    - Crypto Device Supported Functionality Matrices
      http://dpdk.org/doc/guides/cryptodevs/overview.html
  - Sample Applications User Guides
    http://dpdk.org/doc/guides/sample_app_ug/
    - IPsec Security Gateway Sample Application
      http://dpdk.org/doc/guides/sample_app_ug/ipsec_secgw.html
- 01.org
  https://01.org/zh/packet-processing/intel%C2%AE-quickassist-technology-drivers-and-patches?langredirect=1