

Rancher by SUSE

Intel® FlexRAN™ - SUSE Reference Solution Cloud-Native Setup

FlexRAN™ Deployment Guide on SUSE platform



SUSE Linux Enterprise Server 15.3 Real Time

SUSE Linux Enterprise Micro 5.2 Real Time

Rancher 2.6 by SUSE

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Summary

This document provides detailed steps on how to configure Intel® FlexRAN™ 22.07 on SUSE Linux Enterprise 15 SP3 Real-Time (SLES 15 SP3 RT) and deploy FlexRAN™ containers on Rancher Kubernetes Engine v2 (RKE2) cluster running on SUSE Linux Enterprise Micro 5.2 Real Time (SLE Micro RT) as SUSE/Intel Solution for Telco.

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1 Introduction

1.1 Motivation

Intel® FlexRAN™ is a reference implementation for cloud enabled wireless access VNFs. It shows how to efficiently implement wireless access loads through flexible software architecture, Intel® Xeon® Scalable processors using Intel® Advanced Vector Extensions 512 (Intel® AVX 512) instruction set, and optimized NFVi with DPDK.

Executing said implementation is a multi-step process, starting with the Operating System and extensions running on the right hardware, installing Intel® tools, and finally, containerizing and deploying FlexRAN™ in a cloud-native, software-defined infrastructure.

This guide will help you configure and deploy an Intel® FlexRAN™ implementation using SUSE products such as Rancher Server, SUSE Linux Enterprise Server (with Real Time extensions) and SUSE Linux Enterprise Micro Real Time to create and manage Rancher Kubernetes Engine v2 (RKE2) clusters for the containerized implementation.

1.2 Scope

This document provides the necessary steps to setup a cloud-native stack for Intel® FlexRAN™ on SUSE Rancher Kubernetes cluster. This demonstration shows the required steps to install and configure Intel's FlexRAN PHY Reference Design using SUSE Linux Enterprise Server Real Time as the base Operating System and SUSE Linux Enterprise Micro Real Time as target hosts for Rancher RKE2 or K3s Kubernetes cluster with SUSE Rancher Server to manage this deployment.

1.3 Audience

The goal is to empower Telco developers and/or engineers putting together an Intel® FlexRAN™ test and/or proof-of-concept (PoC) environment leveraging the benefits of the complete SUSE stack from the real-time OS to Kubernetes orchestration and management.

2 Prerequisites

This section presents some guidance for the environment into which you deploy Intel® FlexRAN™.

2.1 Hardware

For the FlexRAN™ configuration on the physical development node the following hardware components were used:

Component	Specification
Processor	Intel® Xeon® Silver 4316 @ 2.30Ghz
Memory	128 GB RAM
Network	Intel® vRAN ACC100-based accelerator Intel® E810 100Gb Ethernet controller
Storage	480GB SSD SATA Read Intensive 6Gbps 960GB Data Center NVMe



Note

For more details on server components, see Intel® FlexRAN™ reference documentation:
Installation Guide Software Release v22.07 (Doc. No.: 575834-15.0) and *FlexRAN™ 5GNR Reference Solution 22.07 - PHY Software Documentation (Doc. No.: 603577)*.

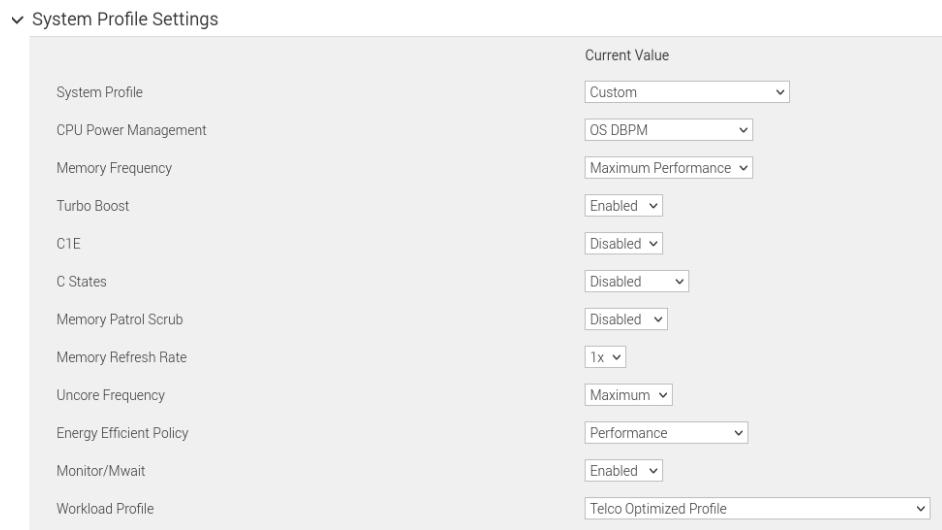
2.2 BIOS Configuration

A server's system BIOS provides runtime services for operating systems and performs hardware initialization during the booting process.

BIOS settings can influence how hardware behaves under different workloads.

Among the most important BIOS settings for implementing Intel® FlexRAN™ are the CPU p-states (optimization of the voltage and CPU frequency during operation) and c-states (optimization of the power consumption if a core does not have to execute any instructions).

BIOS configuration may be different for each server, but most modern servers should have similar settings.



For CPU power management, use *OS DBPM* or a similar control setting to allow the operating system to manipulate processor frequencies.

Depends on the BIOS version, it's also recommended to use a *Custom* profile with a *Telco Optimized* or *Maximum Performance* profile BIOS settings.



Note

For more details, please review section 2.4.2 of *FlexRAN Software Reference Solution Cloud-Native Setup*. (*Intel® Doc. No. 575834-15.0*) and *BIOS Settings for FlexRAN Platforms Based on Intel® Xeon® Processors*. (*Doc. No.: 640685*).

2.3 OS requirements

Intel® FlexRAN™ stipulates a real-time kernel, as listed in *Intel® FlexRAN™ Installation Guide* (*Doc. No.: 575834-15.0*).

For this particular test we used a baremetal node as a development host running SUSE Linux Enterprise 15 SP3 Real-Time to preconfigure and test FlexRAN functionality and build container image before exporting it to a Rancher Kubernetes cluster.

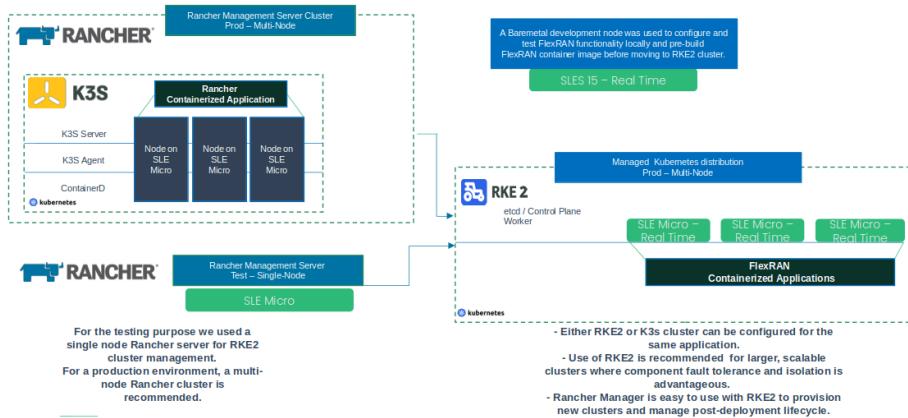


FIGURE 1: TEST SETUP DIAGRAM

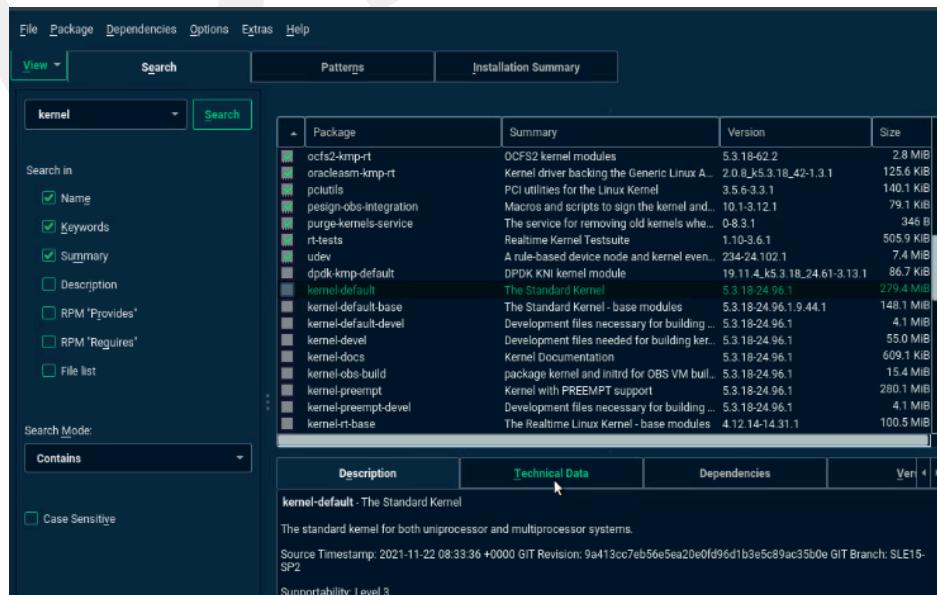
SUSE Linux Enterprise Real Time is a real time operating system designed to reduce latency and increase the predictability and reliability of time-sensitive, business-critical applications.

For more details about SLES RT please review <https://www.suse.com/products/realtime/>

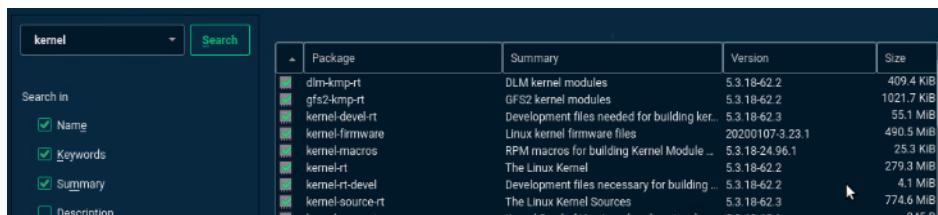
2.3.1 Install SUSE Linux Enterprise Server 15 Real Time

Please refer to the SLES Setup Guide: <https://documentation.suse.com/sle-rt/15-SP3/>

When installing SLES 15 RT, during the installation make sure to unmark *kernel-default*.



Verify *kernel-rt* is selected:



A screenshot of the zypper search interface. The search bar at the top contains the text "kernel". Below the search bar, there is a sidebar with checkboxes for "Search in": "Name" (checked), "Keywords" (checked), "Summary" (checked), and "Description" (unchecked). The main area shows a table with columns: Package, Summary, Version, and Size. The table lists several packages related to the kernel, including "dlm-kmp-rt", "gfs2-kmp-rt", "kernel-devel-rt", "kernel-firmware", "kernel-macros", "kernel-r1", "kernel-rt-devel", and "kernel-source-rt". The "kernel-rt-devel" package is highlighted with a yellow background.

Package	Summary	Version	Size
dlm-kmp-rt	DLM kernel modules	5.3.18-62.2	409.4 KIB
gfs2-kmp-rt	GFS2 kernel modules	5.3.18-62.2	1021.7 KIB
kernel-devel-rt	Development files needed for building ker...	5.3.18-62.3	55.1 MIB
kernel-firmware	Linux kernel firmware files	20200107-3.23.1	490.5 MIB
kernel-macros	RPM macros for building Kernel Module ...	5.3.18-24.96.1	25.3 KIB
kernel-r1	The Linux Kernel	5.3.18-62.2	279.3 MIB
kernel-rt-devel	Development files necessary for building ...	5.3.18-62.2	4.1 MIB
kernel-source-rt	The Linux Kernel Sources	5.3.18-62.3	774.6 MIB



Note

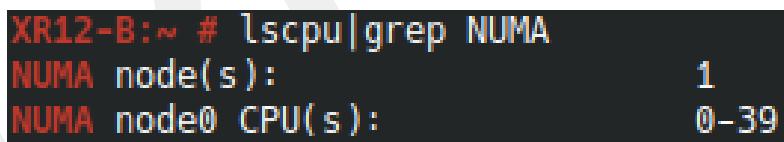
During the installation, add sufficient space to the /opt or /var directories which will be used for most Intel components and containers. We would recommend 200 Gb of storage for these directories. Don't install FlexRAN under root directory.

2.3.2 Real Time configuration

Isolate CPU cores with the following steps:

- Verify that *tuned* installed:

```
zypper in tuned*
```

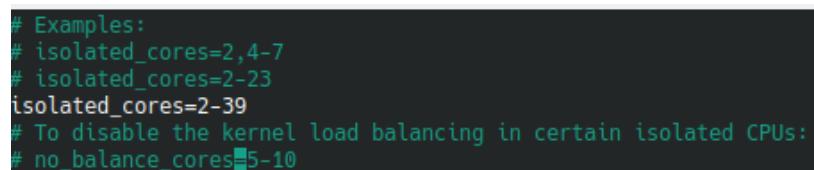


```
XR12-B:~ # lscpu|grep NUMA
NUMA node(s):                      1
NUMA node0 CPU(s):                0-39
```

In our case we have 1 socket and 40 cores.

- Add isolated cores to the configuration

```
vi /etc/tuned/cpu-partitioning-variables.conf
```



```
# Examples:
# isolated_cores=2,4-7
# isolated_cores=2-23
isolated_cores=2-39
# To disable the kernel load balancing in certain isolated CPUs:
# no_balance_cores=5-10
```

- Activate RT profile

```
tuned-adm profile cpu-partitioning
```

For UEFI modify /boot/efi/EFI/sle_rt/grub.cfg
as following:

//

```
set tuned_params="skew_tick=1 nohz=on nohz_full=2-39 rcu_nocbs=2-39 nosoftlockup isolcpus=2-39"
```

```
linuxefi /boot/vmlinuz-5.3.18-150300.96-rt root=UUID=d487d26d-5a91-4c49-a086-4240636a30b8 crashkernel=auto processor.max_cstate=1 intel_pstate=passive nohz=on audit=0 mce=off intel_lommu=on iommu=pt intel_idle.max_cstate=0 idle=poll uscore.autosuspend=-1 selinux=0 enforcing=0 nmi_watchdog=0 nosoftlockup hugepagesz=1G hugepages=40 hugepagesz=2M hugepages=0 default_hugepagesz=1G kthread_cpus=0,1 irqaffinity=0,1 ${extra_cmdline} $tuned_params
```



Note

Settings depend on the number of CPU and isolated cores.
Please review section 2.4.3 of Intel's document 575834-15.0

- Save changes

```
grub2-mkconfig -o /boot/grub2/grub.cfg
```

or for UEFI:

```
grub2-mkconfig -o /boot/efi/EFI/sle_rt/grub.cfg
```

- Reboot server and verify parameters:

```
grep tuned_params= /boot/grub2/grub.cfg
```

```
XR12-B:~ # grep tuned_params= /boot/grub2/grub.cfg
set tuned_params="skew_tick=1 nohz=on nohz_full=2-39 rcu_nocbs=2-39 nosoftlockup isolcpus=2-39"
```

```
cat /proc/cmdline
```

```
XR12-B:~ # cat /proc/cmdline
processor.max_cstate=1 intel_idle.max_cstate=1 skew_tick=1 hpc_cpuset BOOT_IMAGE=/boot/vmlinuz-5.3.18-150300.96-rt root=UUID=d487d26d-5a91-4c49-a086-4240636a30b8 crashkernel=auto processor.max_cstate=1 intel_pstate=passive nohz=on audit=0 mce=off intel_lommu=on iommu=pt intel_idle.max_cstate=0 idle=poll uscore.autosuspend=-1 selinux=0 enforcing=0 nmi_watchdog=0 nosoftlockup hugepagesz=1G hugepages=40 hugepagesz=2M hugepages=0 default_hugepagesz=1G kthread_cpus=0,1 irqaffinity=0,1 skew_tick=1 nohz=on nohz_full=2-39 rcu_nocbs=2-39 nosoftlockup isolcpus=2-39
```

2.4 Set CPU Frequency

AVX512 CPU frequency of your specific CPU should be adjusted according to Figure 4 of Intel's doc Reference Number: 637779, Revision: 1.2 3rd Gen Intel® Xeon® Scalable Processors, Codename Ice Lake NDA Specification Update June 2021 or #613537 for Skylake processor family

SKU	Cores	LLC (MB)	TDP (W)	Base AVX 512 Core Freq (GHz)	# of active cores / maximum core frequency in turbo mode (GHz)																									
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
5320	26	39	185	1.6	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.1	3.1	2.9	2.9	2.7	2.7	2.7	2.6	2.6	2.6	2.6	
6342	24	36	230	2.1	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2		
6338T	24	36	165	1.5	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.1	3.1	2.9	2.9	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5	
6336Y	24	36	185	1.7	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.2	3.2	3.2	3.2	3.1	3.1	2.8	2.8	2.8	2.8	2.8	2.8	
6312U	24	36	185	1.8	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.0	3.0	3.0	3.0	2.8	2.8	2.8	2.8
5318Y	24	36	165	1.5	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.1	3.1	2.9	2.9	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5	
5318S	24	36	165	1.5	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.1	3.1	2.9	2.9	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5	
5318N	24	36	150	1.5	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.0	3.0	2.7	2.7	2.7	2.6	2.6	2.6	2.5	2.5	2.5	2.5	
5320T	20	30	150	1.6	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.0	3.0	2.9	2.9	2.8	2.8	2.7	2.7					
4316	20	30	150	1.6	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	2.9	2.9	2.8	2.8	2.7	2.7	2.6	2.6	2.6	2.6	2.6	
6326	16	24	185	2.1	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1					
4314	16	24	135	1.7	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.0	3.0	2.8	2.8	2.7	2.7									
4317	12	18	150	2.2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

In this deployment Intel® Xeon® 4316 was used with 2.6 GHz.

There are two options to setup your CPU frequency:

- Use cpupower tool

By running

```
cpupower frequency-info
```

you can check available frequencies for your CPU and drivers.

```
Setting cpufreq
XR12-B:/etc/default # cpupower frequency-info
analyzing CPU 0:
driver: intel_cpufreq
CPUs which run at the same hardware frequency: 0
CPUs which need to have their frequency coordinated by software: 0
maximum transition latency: 20.0 us
hardware limits: 800 MHz - 3.40 GHz
available cpufreq governors: userspace ondemand performance schedutil
current policy: frequency should be within 800 MHz and 3.40 GHz.
    The governor "userspace" may decide which speed to use
    within this range.
current CPU frequency: Unable to call hardware
current CPU frequency: 2.60 GHz (asserted by call to kernel)
boost state support:
    Supported: yes
    Active: yes
```

In this example intel_cpufreq was used. The userspace governor is available with the older acpi-cpufreq driver (which will be automatically used if you disable intel_pstate at boot time; you then set the governor/frequency with cpupower)

Set intel_pstate driver to passive in grub (intel_pstate=passive):

```
echo passive | sudo tee /sys/devices/system/cpu/intel_pstate/status
```

or add intel_pstate=passive to the grub:

```
modprobe cpufreq_userspace
```

Set cpu governor to userspace:

```
cpupower frequency-set --governor userspace
```

Set frequency according to the AVX-512 table (2600MHz in this case):

```
cpupower --cpu all frequency-set --freq 2600MHz
```



Note

It's important to set C-state and P-state on the Bios settings as well as on the kernel side. If you don't do this, you won't be able to change governors from the cpupower command and set the cpu frequency. Also, make sure that the BIOS can be changed from the OS by proper setting.

Verify that settings applied by running:

```
turbostat -i 1
```

FCore	CPU	Avg_MHz	Busy%	Bzy_MHz	TSC_MHz	IRQ	SMI	CPU%c1	CPU%c6	CoreTmp	PkgTmp	Pkg%pc2	Pkg%pc6	PkgWatt	RAMWatt	PKG_%	RAM_%
-	-	2594	100.00	2600	1596	6661	0	0.00	0.00	45	45	0.00	0.00	107.91	16.64	0.00	0.00
0	0	2594	100.00	2600	1596	166	0	0.00	0.00	44	45	0.00	0.00	107.91	16.64	0.00	0.00
0	20	2594	100.00	2600	1596	176	0	0.00	0.00								
1	2	2594	100.00	2600	1596	166	0	0.00	0.00	44							
1	22	2594	100.00	2600	1596	165	0	0.00	0.00								
2	4	2594	100.00	2600	1596	166	0	0.00	0.00	44							
2	24	2594	100.00	2600	1596	165	0	0.00	0.00								
3	6	2594	100.00	2600	1596	166	0	0.00	0.00	43							
3	26	2594	100.00	2600	1596	166	0	0.00	0.00								
4	8	2594	100.00	2600	1596	166	0	0.00	0.00	43							
4	28	2594	100.00	2600	1596	166	0	0.00	0.00								
5	10	2594	100.00	2600	1596	166	0	0.00	0.00	43							
5	30	2594	100.00	2600	1596	166	0	0.00	0.00								
6	12	2594	100.00	2600	1596	166	0	0.00	0.00	42							
6	32	2594	100.00	2600	1596	166	0	0.00	0.00								

You can also check with other available tools:

CPU	C0	Cx	Freq
0	99.94	0.06	2593
20	99.94	0.06	2593
2	99.94	0.06	2593
22	99.94	0.06	2593
4	99.94	0.06	2593
24	99.94	0.06	2593
6	99.94	0.06	2593
26	99.94	0.06	2593
8	99.94	0.06	2593
28	99.94	0.06	2593
10	99.94	0.06	2593
30	99.94	0.06	2593
12	99.94	0.06	2593
32	99.94	0.06	2593
14	99.94	0.06	2593
34	99.94	0.06	2593
16	99.94	0.06	2593
36	99.94	0.06	2593
18	99.94	0.06	2593
38	99.94	0.06	2593
1	99.94	0.06	2593

```
XR12-B:~ # grep MHz /proc/cpuinfo
cpu MHz : 2600.000
cpu MHz : 2600.001
cpu MHz : 2600.000
```

- The second option to change AVX512 frequency is to install Intel® msr-tools with the following commands:

```
git clone https://github.com/intel/msr-tools/
cd msr-tools/
git checkout msr-tools-1.3
make
modprobe msr
```

Create bash script setFreq.sh with the following context:

```
#!/bin/bash

cpupower frequency-set -g performance

for i in {0..39}

do

/home/Intel/msr-tools/msr-tools/wrmsr -p $i 0x199 0x1A00

done
```

```
#Set Uncore max frequency

/home/Intel/msr-tools/msr-tools/wrmsr -p 0 0x606A6 0x1A00

/home/Intel/msr-tools/msr-tools/wrmsr -p 39 0x606A6 0x1A00
```



Note

Values in the script were taking from Intel document #637779 (for Ice Lake family) specific to your CPU avx512 numbers. (2.6 GHz in the above example)

Table 2. 3rd Gen Intel® Xeon® Scalable Processors Identification

Processor Number	QDF/S-Spec Number	Die	Stepping	CPUID	Speed (GHz)	DDR4 (MHz)	TDP (W)	# of Cores	LLC Cache Size (MB)	Max. Supported Sockets/Intel UPI Links
4309Y	SRKXS	HCC	M1	0x606A6	2.8	2667	105	8	12	2/2
6342	QXRU	HCC	M1	0x606A6	2.8	3200	230	24	36	2/3
6338T	QXS3	HCC	M1	0x606A6	2.1	3200	165	24	36	2/3
6336Y	QXRV	HCC	M1	0x606A6	2.4	3200	185	24	36	2/3
6334	QXRQ	HCC	M1	0x606A6	3.6	3200	165	8	12	2/3
6326	QXS7	HCC	M1	0x606A6	2.9	3200	185	16	24	2/3
6312U	QXRW	HCC	M1	0x606A6	2.4	3200	185	24	36	1/0
5320T	QXS6	HCC	M1	0x606A6	2.3	2933	150	20	30	2/3
5320	QXRT	HCC	M1	0x606A6	2.2	2933	185	26	39	2/3
5318Y	QXS2	HCC	M1	0x606A6	2.1	2933	165	24	36	2/3
5318S	QRX	HCC	M1	0x606A6	2.1	2933	165	24	36	2/3
5318N	QXS4	HCC	M1	0x606A6	2.1	2667	150	24	36	2/2
5317	QXRM	HCC	M1	0x606A6	3.0	2933	150	12	18	2/3
5315Y	QXRR	HCC	M1	0x606A6	3.2	2933	140	8	12	2/3
4316	QXS5	HCC	M1	0x606A6	2.3	2667	150	20	30	2/2
4314	QXS8	HCC	M1	0x606A6	2.4	2667	135	16	24	2/2
4310T	QXRP	HCC	M1	0x606A6	2.3	2667	105	10	15	2/2
4310	QXRN	HCC	M1	0x606A6	2.1	2667	120	12	18	2/2
4309Y	QXRS	HCC	M1	0x606A6	2.8	2667	105	8	12	2/2

Run the above bash script with your specific numbers which should be changed to the required frequency and verify that required frequency was applied.

Review performance with a Cyclictest:

```
XR12-B:~ # taskset -c 0-19 cyclictest -m -p95 -h 15 -a 1-19 -t 19 --mainaffinity=0
# /dev/cpu_dma_latency set to 0us
policy: fifo: loadavg: 2.76 3.02 2.86 2/1182 14957

T: 0 ( 8667) P:95 I:1000 C:1726624 Min:      1 Act:    2 Avg:    2 Max:      17
T: 1 ( 8668) P:95 I:1000 C:1726630 Min:      2 Act:    2 Avg:    2 Max:      15
T: 2 ( 8669) P:95 I:1000 C:1726629 Min:      2 Act:    3 Avg:    2 Max:      12
T: 3 ( 8670) P:95 I:1000 C:1726629 Min:      2 Act:    2 Avg:    2 Max:      15
T: 4 ( 8671) P:95 I:1000 C:1726629 Min:      2 Act:    2 Avg:    2 Max:      13
T: 5 ( 8672) P:95 I:1000 C:1726628 Min:      2 Act:    2 Avg:    2 Max:      13
T: 6 ( 8673) P:95 I:1000 C:1726628 Min:      2 Act:    2 Avg:    2 Max:      11
T: 7 ( 8674) P:95 I:1000 C:1726628 Min:      2 Act:    2 Avg:    2 Max:      11
T: 8 ( 8675) P:95 I:1000 C:1726627 Min:      2 Act:    2 Avg:    2 Max:      11
T: 9 ( 8676) P:95 I:1000 C:1726627 Min:      2 Act:    2 Avg:    2 Max:      10
T:10 ( 8677) P:95 I:1000 C:1726627 Min:      2 Act:    2 Avg:    2 Max:      13
T:11 ( 8678) P:95 I:1000 C:1726627 Min:      2 Act:    2 Avg:    2 Max:      15
T:12 ( 8679) P:95 I:1000 C:1726626 Min:      2 Act:    2 Avg:    2 Max:      13
T:13 ( 8680) P:95 I:1000 C:1726626 Min:      2 Act:    2 Avg:    2 Max:      11
T:14 ( 8681) P:95 I:1000 C:1726625 Min:      2 Act:    2 Avg:    2 Max:      10
T:15 ( 8682) P:95 I:1000 C:1726625 Min:      2 Act:    2 Avg:    2 Max:      8
T:16 ( 8683) P:95 I:1000 C:1726625 Min:      2 Act:    2 Avg:    2 Max:      12
T:17 ( 8684) P:95 I:1000 C:1726625 Min:      2 Act:    3 Avg:    2 Max:      10
T:18 ( 8685) P:95 I:1000 C:1726624 Min:      2 Act:    3 Avg:    2 Max:      11
```

For more details review [SLE RT Hardware Testing] https://documentation.suse.com/sle-rt/15-SP3/pdf/article-hardware-testing_color_en.pdf

2.5 Install Intel® oneAPI

- Install Intel GPU drivers

That step will eliminate any prerequisites failures for oneAPI.

Review <https://dgpu-docs.intel.com/installation-guides/suse/suse-15sp3.html> for more details.

```
zypper addrepo -r https://repositories.intel.com/graphics/sles/15sp3/intel-graphics.repo
zypper install intel-opencl intel-media-driver libmfx1 intel-level-zero-gpu level-zero
```

- Download and install Intel® oneAPI

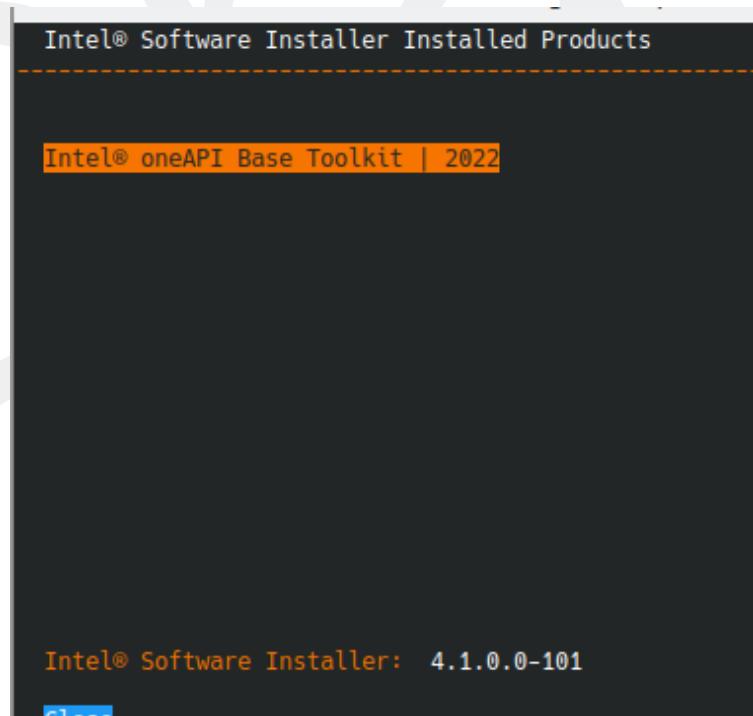
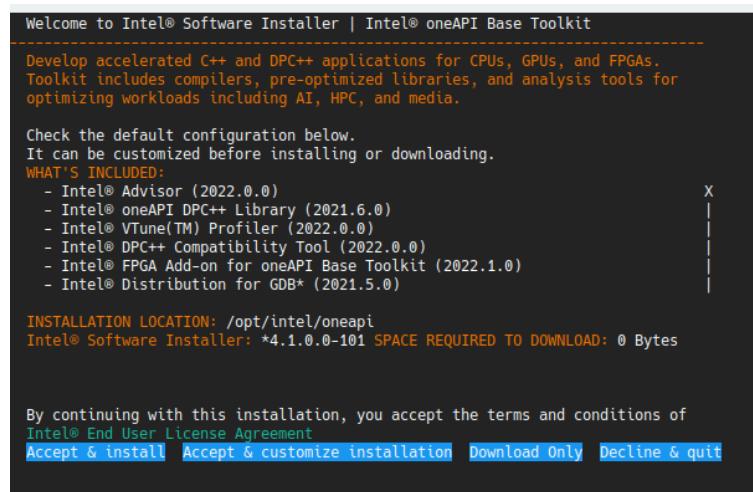
```
wget https://registrationcenter-download.intel.com/akdlm/irc_nas/18236/
l_BaseKit_p_2021.4.0.3422_offline.sh

bash l_BaseKit_p_2021.4.0.3422_offline.sh
```



Note

Make sure that the installation directory has enough space. Intel® oneAPI utilizes approximately 40Gb of space.



Source the environment and verify installed version:

```
XR12-B:/opt/intel/oneapi # source /opt/intel/oneapi/setvars.sh
:: initializing oneAPI environment ...
-bash: BASH_VERSION = 4.4.23(1)-release
args: Using "$@" for setvars.sh arguments:
:: advisor -- latest
:: ccl -- latest
:: compiler -- latest
:: dal -- latest
:: debugger -- latest
:: dev-utilities -- latest
:: dnnl -- latest
:: dpcpp-ct -- latest
:: dpl -- latest
:: intelpython -- latest
:: ipp -- latest
:: ippcpp -- latest
:: mkl -- latest
:: mpi -- latest
:: tbb -- latest
:: vpl -- latest
:: vtune -- latest
:: oneAPI environment initialized ::

XR12-B:/opt/intel/oneapi # icx -v
Intel(R) oneAPI DPC++/C++ Compiler 2022.0.0 (2022.0.0.20211123)
Target: x86_64-unknown-linux-gnu
Thread model: posix
InstalledDir: /opt/intel/oneapi/compiler/2022.0.2/linux/bin-llvm
Found candidate GCC installation: /usr/lib64/gcc/x86_64-suse-linux/7
Selected GCC installation: /usr/lib64/gcc/x86_64-suse-linux/7
Candidate multilib: .;@m64
Selected multilib: .;@m64
```

Make sure that GCC is installed to work with ICX compiler:

```
XR12-B:/etc/default # gcc --version
gcc (SUSE Linux) 7.5.0
Copyright (C) 2017 Free Software Foundation, Inc.
This is free software; see the source for copying conditions. There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
```

3 Intel® FlexRAN™ Installation

Review Compilation tools section of FlexRAN 5GNR Reference Solution 22.07 PHY Software Documentation - Document #603577

Make sure that your instance has installed cmake, meson and ninja.

In order to build the L1 application and L1 standalone Test Application, the following steps are required (in order):

3.1 Install pkgconf tool

```
zypper in automake
```

```
zypper in libtool
git clone https://github.com/pkgconf/pkgconf.git
cd pkgconf/
./configure
make
make install
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:/usr/local/lib
```

```
XR12-B:/var/pkgconf-1.9.3/libpkgconf # pkgconf --version
1.9.3
XR12-B:/var/pkgconf-1.9.3/libpkgconf #
```

3.2 Download and Install DPDK



Note

Don't use /root directory for the installation.
You need to get the dpdk patch from Intel which is required.

```
wget http://static.dpdk.org/rel/dpdk-21.11.tar.xz
tar xf dpdk-21.11.tar.xz
export RTE_SDK=/var/dpdk/dpdk-21.11
```

Copy patch to RTE_SDK directory and apply dpdk patch:

```
patch -p1 < dpdk_patch_21.11.patch
```

3.3 Download and install FlexRAN™

Download FlexRAN™ release as per Intel document 645964.

Extract file and source the environment:

```
tar -zxvf FlexRan-22.07.tar.gz
./extract.sh
export RTE_SDK=/var/dpdk/dpdk-21.11
source ./set_env_var.sh
```

```

XR12-B:/var/FlexRan22.07 # source set_env_var.sh

Compiler not set, defaulting to icx

=====
Environment Variables:
=====

RTE_SDK=/var/dpdk/dpdk-21.11
WIRELESS_SDK_TARGET_ISA=avx512
CPA_DIR=/var/FlexRan22.07/libs/cpa
XRAN_DIR=/var/FlexRan22.07/xran
DIR_WIRELESS_SDK_ROOT=/var/FlexRan22.07/sdk
SDK_BUILD=build-avx512-icx
DIR_WIRELESS_SDK=/var/FlexRan22.07/sdk/build-avx512-icx
FLEXRAN_SDK=/var/FlexRan22.07/sdk/build-avx512-icx/install
DIR_WIRELESS_FW=/var/FlexRan22.07/framework
DIR_WIRELESS_TEST_4G=/var/FlexRan22.07/tests/lte
DIR_WIRELESS_TEST_5G=/var/FlexRan22.07/tests/nr5g
DIR_WIRELESS_TABLE_5G=/var/FlexRan22.07/bin/nr5g/gnb/l1/table
=====

XR12-B:/var/FlexRan22.07 #

```

3.4 Compile SDK

Get `gcc11-c++`:

```
zypper in gcc11-c++
```

Export `PKG_CONFIG_PATH`:

```
export PKG_CONFIG_PATH=$DIR_WIRELESS_SDK/pkgcfg:$PKG_CONFIG_PATH
```

Source oneAPI:

```
source /opt/intel/oneapi/setvars.sh --force

export PATH=/opt/intel/oneapi/compiler/2022.0.2/linux/bin-llvm/:$PATH
```

Review possible compilation options from `./flexran_build.sh -h` command:

```

XR12-B:/var/FlexRan22.07 # ./flexran_build.sh -h
./flexran_build.sh [options]
Options:
-c, --clean      bypasses clean during build process. By default clean is always enabled
-e, --set-env    set environment for the build if not already set elsewhere
-v, --verbose    display all build messages to terminal
-r, --rat        Radio access technology, mandatory option: lte or 5gnr or multi_rat
-t, --isa         specify target isa: avx2 or avx512 or snc or spr (default if not set)
For 5gnr the isa only applies to the SDK component
-x, --compiler   specify target compiler: icc or icx (default if not set)
-o, --old-scheduler enable old framework scheduler option for liapp
-l, --lib-mode    build liapp as a lib, only support 5gnr liapp
-p, --poll-offload enable polling event offloading option, only support 5gnr liapp
-m, --mode       mode of operation / build option. Option can be set multiple times
                sdk - SDK Library
                bbu - Framework Library
                wls - Wireless Shared Memory Library
                mlog - MLog library
                cpa - CPA 5GNR library
                xran - xran library
                liapp - Build L1 Application for radio mode chosen with -r option
                testmac - Build Testmac Application for radio mode chosen with -r option
                testapp - Build Testapp Application for radio mode chosen with -r option
                all - Build all of the above for the specified RAT(s) (default if not set)
                show help info and exit
-h, --help
```

Compile SDK:

```
./flexran_build.sh -x icx -e -r 5gnr -i avx512 -m sdk
```



Note

The FlexRAN SDK libraries must be built first to the provided path before starting the DPDK build process so that software FEC libraries are present.

3.5 Patch and Compile DPDK

```
zypper in python3-pyelftools.rpm
```

Create dpdk script:

```
vi dpdk-dep.sh
```

```
#!/bin/bash
work_path=$PWD
sdk_path= /var/FlexRan22.07/sdk
echo "-----build base dpdk -----"
cd $RTE_SDK; meson build; cd build; meson configure -Dflexran_sdk=$sdk_path/build-avx512-icx/install; ninja
```

Run dpdk script:

```
./dpdk-dep.sh
```

Create dpdk-kmods:

```
git clone http://dpdk.org/git/dpdk-kmods
cd dpdk-kmods/linux/igb_uio/
make
modprobe uio
insmod $RTE_SDK_KMOD/linux/igb_uio/igb_uio.ko
export RTE_SDK_KMOD=/var/dpdk/dpdk-kmods
```

3.6 Build the L1 Application, L1 Standalone Test Application, and Test MAC in Linux:

Verify that you have numa*, libhuge* and libnuma-dev* installed.

Mount hugepages:

```
mount -t hugetlbfs nodev /mnt/huge
```

Compile 5gnr:

```
./flexran_build.sh -x icx -e -r 5gnr
```

Compile lte:

```
./flexran_build.sh -x icx -e -r lte -i avx512
```

After following above steps, upon a successful build, a new L1 application file <instal_l_dir>/bin/nr5g/gnb/l1 will be created. L1 standalone Test Application will be created in <in-stall_dir>/tests/nr5g/nr5g_testapp

- For ACC100 acceleration

Verify acc card:

```
lspci | grep acc  
51:00.0 Processing accelerators: Intel Corporation Device 0d5c
```

```
[RI2-B:/var/pf-bb-config # /var/dpdk/dpdk-21.11/usertools/dpdk-devbind.py -s  
Network devices using kernel driver  
=====  
0000:18:00.0 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em1 drv=bnxt_en unused=igb_uio  
0000:18:00.1 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em2 drv=bnxt_en unused=igb_uio  
0000:18:00.2 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em3 drv=bnxt_en unused=igb_uio  
0000:18:00.3 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em4 drv=bnxt_en unused=igb_uio  
0000:8a:00.0 'Ethernet Controller X710 for 10GBASE-T 15ff' if=p4p1 drv=i40e unused=igb_uio *Active*  
0000:8a:00.1 'Ethernet Controller X710 for 10GBASE-T 15ff' if=p4p2 drv=i40e unused=igb_uio  
  
Other Baseband devices  
=====  
0000:51:00.0 'Device 0d5c' unused=igb_uio
```

When using Mount Bryce (ACC100) acceleration follow <https://github.com/intel/pf-bb-config>

```
git clone https://github.com/intel/pf-bb-config  
cd pf-bb-config/  
make
```

For Physical Function (PF) option:

Bind the PF with the igb_uio module (or alternatively with pci-pf-stub):

```
/var/dpdk/dpdk-21.11/usertools/dpdk-devbind.py --bind=igb_uio 51:00.0
```

Configure the devices using the pf_bb_config application:

```
/var/dpdk/dpdk-21.11/usertools/dpdk-devbind.py --bind=igb_uio 52:00.0 52:00.1
```

```
XR12-B:/var/pf-bb-config # ./pf_bb_config ACC100 -c acc100/acc100_config_2vf_4g5g.cfg
== pf_bb_config Version #VERSION_STRING# ==
Queue Groups: 2 5GUL, 2 5GDL, 2 4GUL, 2 4GDL
Number of 5GUL engines 8
Configuration in VF mode
ROM version MM 99AD92
DDR Training completed in 1369 msPF ACC100 configuration complete
ACC100 PF [0000:51:00.0] configuration complete!
```

For Virtual Function (VF) option:

Create 2 VFs from the PF:

```
XR12-B:/var/pf-bb-config/acc100 # echo 2 | sudo tee /sys/bus/pci/devices/0000:51:00.0/max_vfs
2
```

Check available interfaces:

```
/opt/dpdk/dpdk-stable-20.11.3/usertools/dpdk-devbind.py -s
```

```
XR12-B:/var/pf-bb-config/acc100 # /var/dpdk/dpdk-21.11/usertools/dpdk-devbind.py -s
Network devices using kernel driver
=====
0000:18:00.0 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em1 drv=bnxt_en unused=igb_uio
0000:18:00.1 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em2 drv=bnxt_en unused=igb_uio
0000:18:00.2 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em3 drv=bnxt_en unused=igb_uio
0000:18:00.3 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em4 drv=bnxt_en unused=igb_uio
0000:8a:00.0 'Ethernet Controller X710 for 10GBASE-T 15ff' if=p4p1 drv=i40e unused=igb_uio *Active*
0000:8a:00.1 'Ethernet Controller X710 for 10GBASE-T 15ff' if=p4p2 drv=i40e unused=igb_uio

Baseband devices using DPDK-compatible driver
=====
0000:51:00.0 'Device 0d5c' drv=igb_uio unused=

Other Baseband devices
=====
0000:52:00.0 'Device 0d5d' unused=igb_uio
0000:52:00.1 'Device 0d5d' unused=igb_uio
```

In the above example there are 2 VFs created.

Bind with VF:

```
/var/dpdk/dpdk-21.11/usertools/dpdk-devbind.py --bind=igb_uio 52:00.0 52:00.1
```

Configure the devices using the pf_bb_config application for VF usage with both 5G and 4G enabled.

Select the proper config file for your test for VF:

```
./pf_bb_config ACC100 -c acc100/acc100_config_2vf_4g5g.cfg
```

Check available interfaces and verify number of acc:

```
XR12-B:/var/pf-bb-config # lspci | grep acc
51:00.0 Processing accelerators: Intel Corporation Device 0d5c
52:00.0 Processing accelerators: Intel Corporation Device 0d5d
52:00.1 Processing accelerators: Intel Corporation Device 0d5d
```

Test that the VF is functional on the device using bbdev-test:

```
/var/dpdk/dpdk-21.11/app/test-bbdev # /var/dpdk/dpdk-21.11/build/app/dpdk-test-bbdev -c
F0 -a 52:00.0 -- -c validation -v ./ldpc_dec_default.data
```

```
XR12-B:/var/dpdk/dpdk-21.11/app/test-bbdev # /var/dpdk/dpdk-21.11/build/app/dpdk-test-bbdev -c F0 -a 52:00.0 -- -c validation -v ./ldpc_dec_d
default.data
FlexRAN SDK bplib lte ldpc decoder version jenkins-FlexRAN-github-SDK-REL-113-g11d71e41
FlexRAN SDK bplib lte ldpc encoder version jenkins-FlexRAN-github-SDK-REL-113-g11d71e41
FlexRAN SDK bplib lte LDPC ratematch version jenkins-FlexRAN-github-SDK-REL-113-g11d71e41
FlexRAN SDK bplib lte rate dematching_5gnr version jenkins-FlexRAN-github-SDK-REL-113-g11d71e41
FlexRAN SDK bplib lte turbo version jenkins-FlexRAN-github-SDK-REL-113-g11d71e41
FlexRAN SDK bplib lte crc version jenkins-FlexRAN-github-SDK-REL-113-g11d71e41
FlexRAN SDK bplib lte rate_matching version jenkins-FlexRAN-github-SDK-REL-113-g11d71e41
FlexRAN SDK bplib common version jenkins-FlexRAN-github-SDK-REL-113-g11d71e41
FlexRAN SDK bplib burst_estimate_5gnr version jenkins-FlexRAN-github-SDK-REL-113-g11d71e41
EAL: Detected CPU lcores: 48
EAL: Detected NUMA nodes: 1
EAL: Detected static linkages of DPDK
EAL: Multi-process socket /var/run/dpdk/rte/mp_socket
EAL: Selected IOVA mode 'PA'
EAL: Probe PCI driver: intel_i2c100_vf (8086:1d4d) device: 0000:52:00.0 (socket 0)
TELEMETRY: Telemetry socket created
WARNING: Num of operations was not provided or was set @. Set to default (64)
WARNING: Burst size was not provided or was set @. Set to default (32)
WARNING: Num of lcores was not provided or was set @. Set to value from RTE config (4)

=====
Starting Test Suite : BBdev Validation Tests
Test vector file = ./ldpc_dec_default.data
=====
+-----+
--- test: validation
dev:52:00.0, burst size: 32, num ops: 64, op type: RTE_BBDEV_OP_LDPC_DEC
Operation latency:
    avg: 40375 cycles, 25.2344 us
    min: 38332 cycles, 23.9575 us
    max: 42416 cycles, 26.5113 us
Testcase [ 0 ] : validation_tc passed
+-----+
+ Test Suite Summary : BBdev Validation Tests
+ Tests Total :      1
+ Tests Skipped :    0
+ Tests Passed :     1
+ Tests Failed :     0
+ Tests Lasted :    105.743 ms
+-----+
```

4 Baremetal Host Testing

4.1 FlexRAN L1 and Testmac test

Follow steps from the TestMac section of FlexRAN 5GNR Reference Solution 22.07 PHY Software Documentation - Intel's Document #603577

- Testmac can be built only in the Linux environment using the ICC version recommended in the compilation tools section.
- The source code for the tool is under `source/test/testmac`.
- The make files and projects are under `build/testmac`.
- After building process is completed, the application binary is placed under `bin`.
- To run the application, start the `bin/nr5gnb/testmac\l2.sh` script file. This needs to be run after starting the `l1app` application in timer mode by running `bin/nr5gnb/l1/l1.sh -e`.
- Once the application comes up, you will see a `TESTMAC>` prompt. The same Unit tests can be run using the command:
 - `run rat_type test_type Numerology Bandwidth testnum where`
 - `rat_type` is 0 (LTE), 1 (5GNR)
 - `test_type` is 0 (DL), 1 (UL) or 2 (FD)
 - `Numerology`[0 -> 4], 0=15khz, 1=30khz, 2=60khz, 3=120khz, 4=240khz (for 5GNR only, value is ignored for LTE)
 - `Bandwidth`5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 400 (in MHz) (for 5GNR only, value is ignored for LTE)
 - `testnum` is the Bit Exact TestNum. [1001 -> above] If this is left blank, then all tests under type testtype are run
 - `testnum` is always a 4 digit number. First digit represents the number of carriers to run.
 - For example, to run 5GNR Test Case 5 for Uplink Rx mu=3, 100MHz for 1 carrier, the command would be:
 - `run 1 1 3 100 1005`
 - For example, to run LTE Test Case 5 for Uplink Rx, the command would be:
 - `run 0 1 0 20 1005`



Note

Always source FlexRAN environment and the oneAPI in each tab and make sure that all paths are exported. For simplicity create a script to source all paths every time when running tests in each terminal.

Change dpdkBasebandDevice values from phycfg_timer.xml to either physical or virtual acc:

```
/opt/FlexRan/bin/nr5g/gnb/l1 # vi phycfg_timer.xml
```

For example:

```
<!-- DPDK BBDev name added to the passlist. The argument format is <[domain:]bus:devid.func> -->
<dpdkBasebandDevice>0000:52:00.0</dpdkBasebandDevice>
<!-- VFIO token for DPDK EAL commandline, required when PF is bound to vfio-pci -->
<!--dpdkVfioVfToken>00112233-4455-6677-8899-aabbccddeeff<dpdkVfioVfToken>-->
</DPDK>
```

Where FecMode is set to 1 (HW accelerotor) and 0000:52:00.0 is the VF value from acc. Set dpdkBasebandFecMode to VF value according to your specific card.

From terminal 1 run:

```
./FlexRAN-<version>/bin/nr5g/gnb/l1/l1.sh -e
```

You should be able to see the following console:

```
=====
Non BBU threads in application
=====
phy_print_thread: [PID: 29297] binding on [CPU 0] [PRIO: 0] [POLICY: 1]
wls_rx_handler (non-rt): [PID: 29301] binding on [CPU 0]
=====

PHY>welcome to application console
```

From the 2nd terminal run:

```
/var/FlexRan22.07/bin/nr5g/gnb/testmac # ./l2.sh
```

```
run 1 1 3 100 1005
```

```
4065 4066 4071 4072 4073 4074
TESTMAC>welcome to application console
```

```
TESTMAC>run 1 1 3 100 1005
```

See examples from Document #603577 TestMac section:

- To run the application, start the `bin/nr5gnb/testmacV2.sh` script file. This needs to be run after starting the l1app application in timer mode by running `bin/nr5gnb/l1/11.sh -e`.
 - Once the application comes up, you will see a `TESTMAC>` prompt. The same Unit tests can be run using the command:
 - `run rat_type test_type Numerology Bandwidth testnum` where
 - `rat_type` is 0 (LTE), 1 (5GNR)
 - `test_type` is 0 (DL), 1 (UL) or 2 (FD)
 - `Numerology`[0 > 4], 0=15khz, 1=30khz, 2=60khz, 3=120khz, 4=240khz (for 5GNR only, value is ignored for LTE)
 - `Bandwidth`[5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 400 (in MHz) (for 5GNR only, value is ignored for LTE)
 - `testnum` is the Bit Exact TestNum. [1001 > above] if this is left blank, then all tests under type testtype are run
 - `testnum` is always a 4 digit number. First digit represents the number of carriers to run.
 - For example, to run 5GNR Test Case 5 for Uplink Rx mu=3, 100MHz for 1 carrier, the command would be:
 - run 1 1 3 100 1005
 - For example, to run LTE Test Case 5 for Uplink Rx, the command would be:
 - run 0 1 0 20 1005

The connection should be established in the 1st terminal once you'll run 12.sh from the 2nd terminal:

In the 2nd terminal you should be able to see test result:

```
wls_mac_print_stats:  
    nTotalBlocks[4009] nAllocBlocks[2399] nFreeBlocks[1610] nWaterMarkAllocBlocks[2418]  
    nTotalAllocCnt[2509] nTotalFreeCnt[110] Diff[2399]  
    nDlBufAllocCnt[57] nDlBuffFreeCnt[57] Diff[0]  
    nUlBufAllocCnt[2452] nUlBuffFreeCnt[53] Diff[2399]  
  
All Tests Completed, Total run 1 Tests, PASS 1 Tests, and FAIL 0 Tests  
-----  
mem_mgr_display_size:  
    Num Memory Alloc:           11  
    Total Memory Size:        264,018
```

Another test case is to use a preconfigured test file.

For example from the 2nd terminal run:

```
/var/FlexRan22.07/bin/nr5g/gnb/testmac # ./l2.sh --testfile=/var/FlexRan22.07/bin/nr5g/gnb/testmac/icelake-sp/icxsp_mul_100mhz_4x4_hton.cfg
```

llapp [Time: 0Hr 0Min 20Sec] NumCarrier: 2 NumBbuCores: 3. Tti2Tti Time: [500.00..504.15..510.00] usces								
Latency	usecs			% of TTI				
	Min	Avg	Max	Min	Avg	Max		
DL_LINK_MUI	125.00	202.21	385.00	25%	40%	77%		
UL_LINK_MUI	860.00	875.67	890.00	172%	175%	178%		
SRS_LINK_MUI	0.00	0.00	0.00	0%	0%	0%		
MAC MAC-to-PHY Tput			PHY-to-MAC Tput			UL FEC CB Iterations		
Cell	Inst	kbps	Num CB		kbps	UL BLER	Num CB	Min Avg Max
SRS SNR								
0 (MU 1)	0	300,851	255,968	28,672 /	28,672	0.00%	31,984	1 1.00 1
0 db								
1 (MU 1)	0	300,851	255,968	28,672 /	28,672	0.00%	31,984	1 1.00 1
1 db								

```
mem_mgr_display_size:
  Num Memory Alloc:          12
  Total Memory Size:        268,818

Test[FD_mui_100mhz_4308] Completed
wls_mac_print_stats:
  nTotalBlocks[4009] nAllocBlocks[2399] nFreeBlocks[1610] nWaterMarkAllocBlocks[2874]
  nTotalAllocCnt[82221232] nTotalFreeCnt[82218833] Diff[2399]
  nDlBufAllocCnt[64873831] nDlBuffFreeCnt[64873831] Diff[0]
  nUlBufAllocCnt[17347401] nUlBuffFreeCnt[17345002] Diff[2399]

All Tests Completed, Total run 27 Tests, PASS 21 Tests, and FAIL 6 Tests
mem_mgr_display_size:
  Num Memory Alloc:          11
  Total Memory Size:        264,018
```



Note

Number of failed tests listed above related to a different number of CPU cores defined in the test file.

4.2 CPU set shielding

Another tool for more tuned cores isolation is cpu set shielding.

You can also review CPU manipulation commands from → https://documentation.suse.com/sle-rt/15-SP3/pdf/book-shielding_color_en.pdf

Some examples of using shielding on CPU with integrated tools like cset.

- Create a cset called flexran_set

```
XR12-B:/var/FlexRan22.07/bin/nr5g/gnb/testmac/icelake-sp # cset set -c 7-11 -s flexran_set
cset: --> created cpuset "flexran_set"
XR12-B:/var/FlexRan22.07/bin/nr5g/gnb/testmac/icelake-sp # cset set -
cset:
  Name      CPUs-X    MEMs-X Tasks Subs Path
  root      0-39 y     0 y   1329   3 /
  user      6-10 n     0 n    0     0 /user
  flexran_set 7-11 n   0 n    0     0 /flexran_set
  system    0-5 n     0 n    0     0 /system
```

Example of moving *top* command from root set to flexran_set:

```
XR12-B:/var/FlexRan22.07/bin/nr5g/gnb/testmac/icelake-sp # cset proc -l -s root | grep 6135
root      6103 Soth top
root      6885 35056 Soth grep --color=auto 6135
XR12-B:/var/FlexRan22.07/bin/nr5g/gnb/testmac/icelake-sp # cset proc -m -p 6135 -t flexran_set
cset: moving following pidspec: 6135
cset: moving 1 userspace tasks to /flexran_set
cset: done
XR12-B:/var/FlexRan22.07/bin/nr5g/gnb/testmac/icelake-sp # cset set -l -s flexran_set
cset:
  Name    CPUS-X   MEMS-X Tasks Subs Path
-----
flexran_set  7-11 n     0 n     1     0 /flexran_set
XR12-B:/var/FlexRan22.07/bin/nr5g/gnb/testmac/icelake-sp # cset proc -l -s flexran_set
cset: "flexran_set" cpuset of CPUSPEC(7-11) with 1 task running
USER      PID  PPID SPPr TASK NAME
-----
root      6135  6103 Soth top
```

When starting a testmac you can move pid to a dedicated cset:

```
XR12-B:~ # cset proc -m -p 9319,9444 -t flexran_set
cset: moving following pidspec: 9319,9444
cset: moving 2 userspace tasks to /flexran_set
cset: done

XR12-B:~ # cset proc -l -s flexran_set
cset: "flexran_set" cpuset of CPUSPEC(7-11) with 2 tasks running
USER      PID  PPID SPPr TASK NAME
-----
root      9319  9304 Soth ./liapp --cfgfile=phycfg_timer.xml
root      9444  9436 Soth ./testmac DIR_WIRELESS_TEST_4G=/var/FlexRan22.07/...
```

To move all siblings from pid use *--threads* option:

```
cset proc -m -p 16165 --threads -t two
```

For all features of CPU manipulations please review shielding tasks documents for CPU isolations:

- <https://www.suse.com/c/cpu-isolation-introduction-part-1/>
- https://documentation.suse.com/sle-rt/15-SP3/pdf/book-shielding_color_en.pdf
- https://documentation.suse.com/sle-rt/15-SP3/pdf/article-virtualization_color_en.pdf#%5B%22num%22%3A30%2C%22gen%22%3A0%7D%2C%7B%22name%22%3A%22XYZ%22%7D%2C63.779%2C788.031%2Cnull%5D

To run Testmac with VF set, change setting to proper VF value and configuration

```
XR12-B:/var/pf-bb-config # ./pf_bb_config ACC100 -c acc100/acc100_config_vf_5g.cfg
== pf_bb_config_Version #VERSION_STRING# ==
Queue Groups: 4 5GUL, 4 5GDL, 0 4GUL, 0 4GDL
Number of 5GUL engines 8
Configuration in VF mode
ROM version MM 99AD92
PF ACC100 configuration complete
ACC100 PF [0000:51:00.0] configuration complete!
```

and from the 1st terminal run:

```
./l1.sh -e
```

From the 2nd terminal run:

```
run 1 1 3 100 1005
```

```
-----  
1005 | Result: PASS | DL_IQ: - | PUSCH: P | RXBITS: - | PUCCH: - | MUXSCH: - | SNR: P | TA: P | RACH: - | SRS: - | RI  
P: - | NFLCKR: - | NDEMOD_CW: - | DL_BW: - | UL_BW: - |  
  
wls_mac_print_stats:  
    nTotalBlocks[4009] nAllocBlocks[2399] nFreeBlocks[1610] nWaterMarkAllocBlocks[2417]  
    nTotalAllocCnt[2509] nTotalFreeCnt[118] Diff[2399]  
    nDlBufAllocCnt[57] nDlBufFreeCnt[57] Diff[0]  
    nUlBufAllocCnt[2452] nUlBufFreeCnt[53] Diff[2399]  
  
All Tests Completed, Total run 1 Tests, PASS 1 Tests, and FAIL 0 Tests  
  
mem_mgr_display_size:  
    Num Memory Alloc:           11  
    Total Memory Size:         264.018  
  
-----  
  
XR12-B: # cset proc -m -p 13726,13849 --threads -t flexran_set  
cset: moving following pidspec: 13726,13849,13727,13728,13729,13765,13766,13887,13888,13889,13890,13891  
cset: moving 12 userspace tasks to /flexran_set  
[=====]=%  
cset: done  
-----  
  
XR12-B: # cset proc -l -s flexran_set  
cset: "flexran_set" cpuset of CPUSPEC(7-11) with 12 tasks running  
USER      PID  PPID SPPr TASK NAME  
  
root     13726 13711 Soth ./llapp --cfgfile=phycfg_timer.xml  
root     13727 13711 Soth ./llapp --cfgfile=phycfg_timer.xml  
root     13728 13711 Soth ./llapp --cfgfile=phycfg_timer.xml  
root     13729 13711 Soth ./llapp --cfgfile=phycfg_timer.xml  
root     13765 13711 Soth ./llapp --cfgfile=phycfg_timer.xml  
root     13766 13711 Soth ./llapp --cfgfile=phycfg_timer.xml  
root     13849 13841 Soth ./testmac DIR_WIRELESS_TEST_4G=/var/FlexRan22.07/...  
root     13887 13841 Soth ./testmac DIR_WIRELESS_TEST_4G=/var/FlexRan22.07/...  
root     13888 13841 Soth ./testmac DIR_WIRELESS_TEST_4G=/var/FlexRan22.07/...  
root     13889 13841 Soth ./testmac DIR_WIRELESS_TEST_4G=/var/FlexRan22.07/...  
root     13890 13841 Sf90 ./testmac DIR_WIRELESS_TEST_4G=/var/FlexRan22.07/...  
root     13891 13841 Sf89 ./testmac DIR_WIRELESS_TEST_4G=/var/FlexRan22.07/...
```

If using a config file, from the 2nd terminal run:

```
./l2.sh --testfile=/var/FlexRan22.07/bin/nr5g/gnb/testmac/icelake-sp/  
icxsp_mul_100mhz_mmimo_32x32_hton.cfg
```

If using a *taskset*, from terminal 1 run:

```
~/gnb/l1 # taskset -c 12-19 ./l1.sh -e
```

and from terminal 2 run:

```
~/gnb/testmac # taskset -c 12-19 ./l2.sh
```

5 Deploy FlexRAN™ on Container through Kubernetes

5.1 Generate LTE/5G Docker Images with pre-build FlexRAN™

All prerequisite components and FlexRAN™ should be installed as described in the previous sections.

The main document to follow: FlexRAN Reference Solution Cloud-Native Setup (Intel Document Number: 575834-15.0)

Use existing FlexRAN directory or create a FlexRAN pre-configured directory which will be used for the container image.

Source all environment variables:

```
export RTE_SDK=/var/dpdk/dpdk-21.11
source /opt/intel/oneapi/setvars.sh
export PKG_CONFIG_PATH=$DIR_WIRELESS_SDK/pkgcfg:$PKG_CONFIG_PATH
source set_env_var.sh
```

5.1.1 Create a Dockerfile

If you want to deploy a SUSE Linux Enterprise-based container to deploy to the cluster in the future, follow the steps below.

- Modify *flexran_build_dockerfile.sh* from the flexran directory:

```

OS_TYPE_sle='ls /boot/efi/EFI/ | grep sle'
if [ -n "$OS_TYPE_sle" ]; then
    if [ -z $http_proxy ];then
        cat > flexran_build/Dockerfile << EOF
FROM registry.suse.com/suse/sle15:15.3
ENV no_proxy "localhost,127.0.0.1,192.168.0.100"
ADD http://192.168.150.160/repo/rmt-server.crt /etc/pki/trust/anchors/rmt.crt
ARG ADDITIONAL_MODULES
RUN update-ca-certificates
RUN zypper --gpg-auto-import-keys ref -s
RUN zypper ref && zypper --non-interactive in libhugetlbfs libhugetlbfs-devel gcc11-c++ numactl ethtool
ol gcc make kmod wget patch iproute2 pciutils python vim cmake unzip iutils libaio1 libaio-devel git
git-core net-tools gawk
ENV WIRELESS_SDK_TARGET_ISA=avx512 CPA_DIR=/opt/flexran/libs/cpa XRN_DIR=/opt/flexran/xran DIR_WIRELESS_SDK_ROOT=/opt/flexran/sdk SDK_BUILD=build-avx512-icx DIR_WIRELESS_SDK=/opt/flexran/sdk/build-avx512-icx FLEXRAN_SDK=/opt/flexran/sdk/build-avx512-icx/install DIR_WIRELESS_FW=/opt/flexran/framework DIR_WIRELESS_TEST_4G=/opt/flexran/tests/lte DIR_WIRELESS_TEST_5G=/opt/flexran/tests/nr5g DIR_WIRELESS_TABLE_E_5G=/opt/flexran/bin/nr5g/gnb/l1/table
WORKDIR /var/
COPY flexran ./flexran
COPY oneapi /opt/oneapi
COPY docker_entry.sh .
EOF
else
    cat > $tmp_path/Dockerfile << EOF
FROM registry.suse.com/suse/sle15:15.3
# ENV http_proxy $http_proxy
# ENV https_proxy $https_proxy
RUN zypper ref && zypper --non-interactive in libhugetlbfs libhugetlbfs-devel numactl ethtool gcc make
kmod wget patch iproute2 pciutils python vim cmake unzip iutils libaio1 libaio-devel git git-core net-tools gawk
ENV WIRELESS_SDK_TARGET_ISA=avx512 CPA_DIR=/opt/flexran/libs/cpa XRN_DIR=/opt/flexran/xran DIR_WIRELESS_SDK_ROOT=/opt/flexran/sdk SDK_BUILD=build-avx512-icx DIR_WIRELESS_SDK=/opt/flexran/sdk/build-avx512-icx FLEXRAN_SDK=/opt/flexran/sdk/build-avx512-icx/install DIR_WIRELESS_FW=/opt/flexran/framework DIR_WIRELESS_TEST_4G=/opt/flexran/tests/lte DIR_WIRELESS_TEST_5G=/opt/flexran/tests/nr5g DIR_WIRELESS_TABLE_E_5G=/opt/flexran/bin/nr5g/gnb/l1/table
WORKDIR /var/

```



Note

Modify according to your local setup. If local RMT server is used, you need to post rmt-server.crt file on your RMT server in the location which can be reachable from url. So, on the local RMT server copy */etc/rmt/ssl/rmt-server.crt* file to the */usr/share/rmt/public/repo* directory, which creates symb link to *./var/lib/rmt/public/repo* which is a public repo of RMT server. Setup a proper permission to */usr/share/rmt/public/repo* directory. Sync rmt server.

- Build a docker image:

```
./flexran_build_dockerfile_suse.sh -v -e avx512 -r 5gnr -m all -x icx
```

```

Step 1/12 : FROM registry.suse.com/suse/sle15:15.3
--> 930b2987992e
Step 2/12 : ENV no_proxy "localhost,127.0.0.1,192.168.0.100"
--> Using cache
--> 930b2987992e
Step 3/12 : ADD http://192.168.158.168/repo/rmt-server.crt /etc/pki/trust/anchors/rmt.crt
Downloaded https://192.168.158.168/repo/rmt-server.crt [https://192.168.158.168/repo/rmt-server.crt] 2.676kB/2.676kB
Step 4/12 : RUN curl -s https://192.168.158.168/repo/rmt-server.crt > /etc/pki/trust/anchors/rmt.crt
--> Using cache
--> 6363c30f3a93
Step 5/12 : RUN rpm --import /etc/pki/trust/anchors/rmt.crt
--> Using cache
--> 87a3534a2777
Step 6/12 : RUN zypper --gpg-auto-import-keys ref -
--> Using cache
Step 7/12 : RUN zypper ref && zypper --non-interactive install libhugetlbfs libhugetlbfs-devel gcc11-c++ numactl ethtool gcc make knomd wget patch iproute2 pciutils pytho
n vim cmake unzip iputils libtai libtai-devel git git-core net-tools gawk
--> Using cache
--> c81729973a9b
Step 8/12 : RUN curl -s https://github.com/intel/flexran/releases/download/v1.2.0/flexran_v1.2.0_x86_64.tar.gz > flexran_v1.2.0_x86_64.tar.gz
Step 9/12 : ENV DIR_WIRELESS_SDK TARGET_JSA=avx512 CPA_DIR=/opt/flexran/libs/cpa_XMAN_DIR=/opt/flexran/xman DIR_WIRELESS_SDK_ROOT=/opt/flexran/sdk SDK_BUILD=build-pv
x512-lcx DIR_WIRELESS_SDK=/opt/flexran/sdk/build-avx512-lcx FLEXMAN_SDK=/opt/flexran/sdk/build-avx512-lcx/install1 DIR_WIRELESS_Fwk=/opt/flexran/framework DIR_WIRE
LESS_TEST_4G=/opt/flexran/tests/lte DIR_WIRELESS_TABLES=/opt/flexran/tests/mR5g DIR_WIRELESS_TABLE=mR5g/gnb/li/table
--> Using cache
--> 327c8c5ff7d8
Step 10/12 : WORKDIR /var/
--> Using cache
--> 1d121eeef8d5
Step 11/12 : COPY flexran_v1.2.0_x86_64.tar.gz .
--> 855bb1b0e15
Step 12/12 : COPY oneopi /opt/oneopi
--> 6cd2c2d7f234
Step 13/14 : RUN ./ocker_entry.sh .
--> a3bd9dcf855
Successfully built a3bd9dcf855
Successfully tagged flexran.docker.registry/flexran_vdu:latest

```

- Tag a docker image:

```
docker tag flexran.docker.registry/flexran_vdu:latest flexran.docker.registry/
flexran_vdu:22.07
```

```

XR12-B:/var/flexran # docker images
REPOSITORY          TAG        IMAGE ID      CREATED       SIZE
flexran.docker.registry/flexran_vdu   22.07     a3bd9dcf855  18 minutes ago  3.28GB
flexran.docker.registry/flexran_vdu   latest    a3bd9dcf855  18 minutes ago  3.28GB
<none>              <none>    da59789acc20  4 hours ago   731MB
registry.suse.com/suse/sle15        15.3      70f6a29ec59d  4 days ago    117MB
rancher/rancher-agent             v2.6.2    615d5b746927  10 months ago  495MB
rancher/hyperkube                 v1.21.5-rancher1 327c8c5ff7d8  12 months ago  1.9GB
rancher/rke-tools                  v0.1.78   6eeaa0b8da2c  13 months ago  264MB
rancher/mirrored-coreos-etcd       v3.4.16-rancher1 532c4733c665  16 months ago  83.9MB

```



Note

Another alternative and recommended tool to use is podman since it's daemonless and has integration with cockpit web console on Sle Micro. For that you need to replace *docker build* command with *podman* in *flexran_build_dockerfile.sh* file and run:

```
podman build -t
```

For more details review the Podman guide: https://documentation.suse.com/sle-micro/5.1/pdf/article-podman_color_en.pdf

- Prepare file to export to the target node and save docker as:

```
docker save flexran.docker.registry/flexran_vdu:22.07|gzip > flexranimage.tar.gz
```

5.2 Create an RKE2 cluster

5.2.1 Install SUSE Linux Enterprise Micro

In this test deployment, SUSE Linux Enterprise Micro 5.2 (SLE Micro) was used as a server host for the Rancher server test deployment.

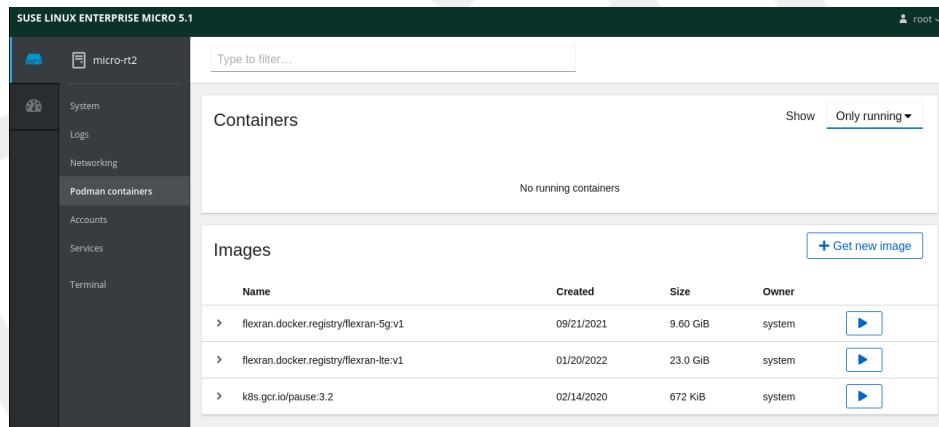
SUSE Linux Enterprise Micro is a lightweight and secure OS platform purpose built for containerized and virtualized workloads.

For more details on installation of SLE Micro, review: https://documentation.suse.com/sle-micro/5.2/pdf/book-deployment-slemicro_color_en.pdf

After installing a SLE Micro you can enable a cockpit console for easy management:

```
systemctl enable --now cockpit.socket
```

and open console in the browser as '<https://your-ip:9090/>'



For more details review:

<https://documentation.suse.com/sle-micro/5.2/>

5.2.2 Install a Rancher server

Install K3s:

```
curl -sfL https://get.k3s.io | INSTALL_K3S_VERSION="v1.23.9+k3s1" \
INSTALL_K3S_SKIP_SELINUX_RPM=true INSTALL_K3S_EXEC='server --cluster-init --write-kubeconfig-mode=644' sh -s -
```

Install certificates and verify:

```
kubectl apply --validate=false -f https://github.com/cert-manager/cert-manager/releases/download/v1.7.1/cert-manager.crds.yaml  
helm repo add jetstack https://charts.jetstack.io  
helm repo update  
export KUBECONFIG=/etc/rancher/k3s/k3s.yaml  
helm install cert-manager jetstack/cert-manager --namespace cert-manager --create-namespace --version v1.7.1
```

```
kubectl get pods --namespace cert-manager
```

```
rancher-server2:/opt # kubectl get pods --namespace cert-manager  
NAME READY STATUS RESTARTS AGE  
cert-manager-76d44b459c-jxm67 1/1 Running 0 8m38s  
cert-manager-cainjector-9b679cc6-rs4vc 1/1 Running 0 8m38s  
cert-manager-webhook-57c994b6b9-x6xc9 1/1 Running 0 8m38s
```

Install Rancher:

```
helm repo add rancher-stable https://releases.rancher.com/server-charts/stable  
kubectl create namespace cattle-system  
export HOSTNAME="rancher-server2.isv.suse"  
export RANCHER_VERSION="2.6.5"  
helm install rancher rancher-stable/rancher --namespace cattle-system --set  
hostname=rancher-server2.isv.suse --set version=2.6.5 --set replicas=1
```

Go to Rancher url and login.

For more details on Rancher installation, review > https://documentation.suse.com/trd/kubernetes/pdf/kubernetes_ri_rancher-k3s-slemicro_color_en.pdf

5.2.3 Create a custom RKE2 cluster

- From the Rancher server create a custom cluster > switch to rke2

Cluster: Create Custom

Cluster Name *	flexran-rke2	Cluster Description	Intel FlexRan demo
Cluster Configuration			
<p>Basics</p> <p>Member Roles</p> <p>Add-On Config</p> <p>Agent Environment Vars</p> <p>etcd</p> <p>Labels & Annotations</p> <p>Networking</p> <p>Registries</p> <p>Upgrade Strategy</p> <p>Advanced</p>			
Kubernetes Version	v1.23.10+rke2r1	Show deprecated Kubernetes patch versions	Cloud Provider (None)
Container Network	multus.calico		
<p>Security</p> <p>Default Pod Security Policy</p> <p>unrestricted</p> <p>Worker CIS Profile (None)</p>			
<p>System Services</p> <p><input checked="" type="checkbox"/> CoreDNS <input checked="" type="checkbox"/> NGINX Ingress <input checked="" type="checkbox"/> Metrics Server</p>			

- Copy registration script to a new node to add it to the cluster:

Cluster: flexran-rke2 (Reconciling)

Namespace: fleet-default Age: 3 secs

This resource is currently in a transitioning state, but there isn't a detailed message available.

Description: Intel FlexRan cluster
Provisioner: RKE2

Machines Provisioning Log Registration Snapshots Conditions Related Resources

You should not import a cluster which has already been connected to another instance of Rancher as it will lead to data corruption.

Step 1

Node Role

Choose what roles the node will have in the cluster. The cluster needs to have at least one node with each role.

etcd Control Plane Worker

Show Advanced

Step 2

Registration Command

Run this command on each of the existing Linux machines you want to register.

```
curl --insecure -fL https://rancher-server2.svc.suse:443/system-agent-install.sh | sudo sh -s - --server https://rancher-server2.svc.suse:443 --label 'cattle.io/os=linux' --token rp55dcwlvswvnxfrsnzqvhmlj6vngmwx5m4hk5sd1xh4dff8f7t4 --ca-checksum 170ee5728747cebe9633b7c6ebb3686749b4b4791a1343fb54bc382cff0b8 --etcd --controlplane --worker
```

Insecure: Select this to skip TLS verification if your server has a self-signed certificate.

- Verify if machines got provisioned:

Cluster: flexran-rke2 (Reconciling)
Namespace: fleet-default Age: 3 secs
This resource is currently in a transitioning state, but there isn't a detailed message available.
Description: Intel FlexRan cluster
Provisioner: RKE2

Machines Provisioning Log Registration Snapshots Conditions Related Resources

You should not import a cluster which has already been connected to another instance of Rancher as it will lead to data corruption.

Step 1
Node Role
Choose what roles the node will have in the cluster. The cluster needs to have at least one node with each role.
 etcd Control Plane Worker

Show Advanced

Step 2
Registration Command
Run this command on each of the existing Linux machines you want to register.
curl --insecure -fL https://rancher-server2.isv.suse:443/system-agent-install.sh | sudo sh -s - --server https://rancher-server2.isv.suse:443 --label 'cattle.io/os=linux' --token rp55dcwlvsmvnxfrsnzqvhmlj6enqnwxss54hk5sd1x14dff8f7t4 --ca-checksum 170ee57287477cebee9633b7c6ebb3686749b4b4a791a1343fb54bc382cff0b8 --etcd --controlplane --worker

Insecure: Select this to skip TLS verification if your server has a self-signed certificate.

```
kubectl get nodes
NAME     STATUS   ROLES          AGE     VERSION
xr12-a   Ready    control-plane,etcd,master,worker   7d21h   v1.23.10+rke2r1
xr12-c   Ready    control-plane,etcd,master,worker   7d20h   v1.23.10+rke2r1
```

In this test case 2 Dell XR12 nodes were used with SLE Micro 5.2 RT installed as part of the RKE2 cluster. Both target nodes should have dpdk with a patch and Intel oneAPI installed.

For core isolation on SLE Micro RT, install *tuned* package with additional dependencies.

```
transactional-update pkg install tuned.rpm python3-configobj.rpm python3-linux-procfs.rpm
python3-pyudev.rpm virt-what.rpm
```



Note

For this test, SLES 15 repositories were used with *curl* commands to download packages locally. For a large scale deployment a local repository can be made with required RPMs.

Modify */etc/default/grub* to the required tuned parameters with *isolcpu* and run transactional-update *grub.cfg* to save changes and reboot.



Note

When setting up CPU Manager for Kubernetes* (CMK*) it should be based on *isolcpu* settings in GRUB. Make sure that all required plugins for Kubernetes for your test are installed on tested nodes as described in section 4 of Intel's document 575834-15.0



Note

It's not recommended to add a FlexRAN™ development node to the RKE2 cluster. Instead, move image to the FlexRAN™ RKE2 cluster, either manually or with a repo.

During our RKE2 cluster deployment, Rancher provides an option to select Multus and Calico as default plugins, so no needs to install them manually.

5.3 Build SR-IOV Network Device Plugin

The setup details for virtual or physical functions of the SR-IOV Network Device Plugins can be found at: <https://github.com/k8snetworkplumbingwg/sriov-network-device-plugin>

```
cd /root/go/src/github.com/intel/  
~/go/src/github.com/intel # git clone https://github.com/intel/sriov-network-device-  
plugin  
cd sriov-network-device-plugin/  
git checkout v3.5.1  
mkdir bin  
cp ~/go/bin/golint bin/  
~/go/src/github.com/intel/sriov-network-device-plugin # make  
make image
```

Tag with:

```
docker tag ghcr.io/k8snetworkplumbingwg/sriov-network-device-plugin:latest nfvpe/sriov-  
device-plugin:v3.5
```

```
KR12-B:/var # docker images  
REPOSITORY                                     TAG      IMAGE ID   CREATED        SIZE  
nfvpe/sriov-device-plugin                      v3.5    2b4f0d8d3133 7 minutes ago  49MB  
ghcr.io/k8snetworkplumbingwg/sriov-network-device-plugin  latest  2b4f0d8d3133 7 minutes ago  49MB  
<none>                                         <none>  11ab97ff9dc6 7 minutes ago  1.04GB  
flexran.docker.registry/flexran_vdu            22.07   a3bd9dcefb55 2 days ago   3.28GB  
flexran.docker.registry/flexran_vdu            latest   a3bd9dcefb55 2 days ago   3.28GB  
<none>                                         <none>  da59789acc20 2 days ago   731MB  
registry.suse.com/suse/sle15                  15.3    70f6a29ec59d 6 days ago   117MB  
golang                                         1.18-alpine b68eed002951 8 days ago   328MB  
alpine                                         3       9c6f07244728 5 weeks ago  5.54MB  
rancher/rancher-agent                         v2.6.2   615d5b746927 11 months ago 495MB  
rancher/hyperkube                            v1.21.5-rancher1 327c8c5ff7b8 12 months ago 1.9GB  
rancher/rke-tools                            v0.1.78   6eaa0b8da2c 14 months ago 264MB  
rancher/mirrored-coreos-etcd                 v3.4.16-rancher1 532c4733c665 16 months ago 83.9MB  
KR12-B:/var #
```

Save with:

```
docker save nfvpe/sriov-device-plugin:v3.5|gzip > sriov-device-plugin.tar.gz
```

5.4 Create FlexRAN™ Pods

Label nodes as:

```
kubectl label nodes xr12-b testnode=worker1
```

```
[xr12-B:~]# kubectl get nodes --show-labels
NAME     STATUS   ROLES          AGE    VERSION   LABELS
xr12-a   Ready    control-plane,etcd,master,worker   2d1h   v1.23.10+rke2r1   beta.kubernetes.io/arch=amd64,beta.kubernetes.io/instance-type=rke2,beta.kubernetes.io/os=linux,cattle.io/os=linux,egress.rke2.io/cluster=true,kubernetes.io/arch=amd64,kubernetes.io/hostname=xr12-a,kubernetes.io/os=linux,node-role.kubernetes.io/control-plane=true,node-role.kubernetes.io/etcd=true,node-role.kubernetes.io/master=true,node-role.kubernetes.io/worker=true,node.kubernetes.io/instance-type=rke2,plan.upgrade.cattle.io/system-agent-upgrader=3116a77386dbd2c53715c761885d4e41068b854f7aaaf35cd0b989315,rke.cattle.io/machine=887d1931-26fc-4a51-9fb4-19f51a3c11
xr12-b   Ready    control-plane,etcd,master,worker   2d1h   v1.23.10+rke2r1   beta.kubernetes.io/arch=amd64,beta.kubernetes.io/instance-type=rke2,beta.kubernetes.io/os=linux,cattle.io/os=linux,egress.rke2.io/cluster=true,kubernetes.io/arch=amd64,kubernetes.io/hostname=xr12-b,kubernetes.io/os=linux,node-role.kubernetes.io/control-plane=true,node-role.kubernetes.io/etcd=true,node-role.kubernetes.io/master=true,node-role.kubernetes.io/worker=true,node.kubernetes.io/instance-type=rke2,plan.upgrade.cattle.io/system-agent-upgrader=3116a77386dbd2c53715c761885d4e41068b854f7aaaf35cd0b989315,rke.cattle.io/machine=3f6c951a-40af-4744-beab-2ca5f1759
07.testnode=worker1
xr12-c   Ready    control-plane,etcd,master,worker   2d1h   v1.23.10+rke2r1   beta.kubernetes.io/arch=amd64,beta.kubernetes.io/instance-type=rke2,beta.kubernetes.io/os=linux,cattle.io/os=linux,egress.rke2.io/cluster=true,kubernetes.io/arch=amd64,kubernetes.io/hostname=xr12-c,kubernetes.io/os=linux,node-role.kubernetes.io/control-plane=true,node-role.kubernetes.io/etcd=true,node-role.kubernetes.io/master=true,node-role.kubernetes.io/worker=true,node.kubernetes.io/instance-type=rke2,plan.upgrade.cattle.io/system-agent-upgrader=3116a77386dbd2c53715c761885d4e41068b854f7aaaf35cd0b989315,rke.cattle.io/machine=94a6b57a-5359-4e23-abf9-7f28a7727
0b
```

- Configure FEC and FVL SRIOV

To reconfigure pf_bb_config run:

```
pkill pf_bb_config
modprobe vfio-pci enable_sriov=1 disable_idle_d3=1
insmod /var/dpdk/dpdk-kmods/linux/igb_uio/igb_uio.ko
/var/dpdk/dpdk-21.11/usertools/dpdk-devbind.py -b igb_uio 18:00.0
```

where 18:00.0 is acc pf address

Check available accelerator cards:

```
lspci|grep acc
18:00.0 Processing accelerators: Intel Corporation Device 0d5c
```

Add 4 VFs to acc:

```
echo 4 > /sys/bus/pci/devices/0000:18:00.0/max_vfs
```

Verify:

```
[XR12-B:/var/dpdk/dpdk-21.11/usertools]# dpdk-devbind.py -s
Network devices using kernel driver
=====
0000:1b:00.0 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em1 drv=bnxt_en unused=igb_uio,vfio-pci
0000:1b:00.1 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em2 drv=bnxt_en unused=igb_uio,vfio-pci
0000:1b:00.2 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em3 drv=bnxt_en unused=igb_uio,vfio-pci
0000:1b:00.3 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751' if=em4 drv=bnxt_en unused=igb_uio,vfio-pci
0000:51:00.0 'Ethernet Controller E810-C for QSFP 1592' if=p2p1 drv=ice unused=igb_uio,vfio-pci *Active*
0000:51:00.1 'Ethernet Controller E810-C for QSFP 1592' if=p2p2 drv=ice unused=igb_uio,vfio-pci
0000:8a:00.0 'Ethernet Controller X710 for 10GBASE-T 15ff' if=p4p1 drv=i40e unused=igb_uio,vfio-pci *Active*
0000:8a:00.1 'Ethernet Controller X710 for 10GBASE-T 15ff' if=p4p2 drv=i40e unused=igb_uio,vfio-pci

Baseband devices using DPDK-compatible driver
=====
0000:18:00.0 'Device 0d5d' drv=igb_uio unused=vfio-pci

Other Baseband devices
=====
0000:19:00.0 'Device 0d5d' unused=igb_uio,vfio-pci
0000:19:00.1 'Device 0d5d' unused=igb_uio,vfio-pci
0000:19:00.2 'Device 0d5d' unused=igb_uio,vfio-pci
0000:19:00.3 'Device 0d5d' unused=igb_uio,vfio-pci
```

In the below example 4 new were created:

```
lspci|grep acc
18:00.0 Processing accelerators: Intel Corporation Device 0d5c
19:00.0 Processing accelerators: Intel Corporation Device 0d5d
19:00.1 Processing accelerators: Intel Corporation Device 0d5d
19:00.2 Processing accelerators: Intel Corporation Device 0d5d
19:00.3 Processing accelerators: Intel Corporation Device 0d5d
```

```
Network devices using DPDK-compatible driver
=====
0000:51:01.0 'Ethernet Adaptive Virtual Function 1889'drv=vfio-pci unused=lavf,igb_uio
0000:51:01.1 'Ethernet Adaptive Virtual Function 1889'drv=vfio-pci unused=lavf,igb_uio
0000:51:01.2 'Ethernet Adaptive Virtual Function 1889'drv=vfio-pci unused=lavf,igb_uio
0000:51:01.3 'Ethernet Adaptive Virtual Function 1889'drv=vfio-pci unused=lavf,igb_uio
0000:51:11.0 'Ethernet Adaptive Virtual Function 1889'drv=vfio-pci unused=lavf,igb_uio
0000:51:11.1 'Ethernet Adaptive Virtual Function 1889'drv=vfio-pci unused=lavf,igb_uio
0000:51:11.2 'Ethernet Adaptive Virtual Function 1889'drv=vfio-pci unused=lavf,igb_uio
0000:51:11.3 'Ethernet Adaptive Virtual Function 1889'drv=vfio-pci unused=lavf,igb_uio

Network devices using kernel driver
=====
0000:1b:00.0 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751'if=em1drv=bnxt_en unused=igb_uio,vfio-pci
0000:1b:00.1 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751'if=em2drv=bnxt_en unused=igb_uio,vfio-pci
0000:1b:00.2 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751'if=em3drv=bnxt_en unused=igb_uio,vfio-pci
0000:1b:00.3 'BCM57504 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet 1751'if=em4drv=bnxt_en unused=igb_uio,vfio-pci
0000:51:00.0 'Ethernet Controller E810-C for QSFP 1592'if=p2p1drv=ice unused=igb_uio,vfio-pci *Active*
0000:51:00.1 'Ethernet Controller E810-C for QSFP 1592'if=p2p2drv=ice unused=igb_uio,vfio-pci
0000:51:01.4 'Ethernet Adaptive Virtual Function 1889'if=drv=lavf unused=igb_uio,vfio-pci
0000:51:01.5 'Ethernet Adaptive Virtual Function 1889'if=p2p1_5drv=lavf unused=igb_uio,vfio-pci
0000:51:11.4 'Ethernet Adaptive Virtual Function 1889'if=p2p2_4drv=lavf unused=igb_uio,vfio-pci
0000:51:11.5 'Ethernet Adaptive Virtual Function 1889'if=p2p2_5drv=lavf unused=igb_uio,vfio-pci
0000:8a:00.0 'Ethernet Controller X710 for 10GBASE-T 15ff'if=p4pdrv=drv=140e unused=igb_uio,vfio-pci *Active*
0000:8a:00.1 'Ethernet Controller X710 for 10GBASE-T 15ff'if=p4p2drv=drv=140e unused=igb_uio,vfio-pci

Baseband devices using DPDK-compatible driver
=====
0000:18:00.0 'Device 0d5c'drv=igb_uio unused=vfio-pci
0000:19:00.0 'Device 0d5d'drv=vfio-pci unused=igb_uio
0000:19:00.1 'Device 0d5d'drv=vfio-pci unused=igb_uio
0000:19:00.2 'Device 0d5d'drv=vfio-pci unused=igb_uio
0000:19:00.3 'Device 0d5d'drv=vfio-pci unused=igb_uio
```

```
7: p2p1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP mode DEFAULT group default qlen 1000
    link/ether b4:96:91:b4:4d:08 brd ff:ff:ff:ff:ff:ff
    vf 0    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 1    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 2    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 3    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 4    link/ether 92:8a:e3:5e:d9:c8 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 5    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    altname enp81s0f0
8: p4p2: <BROADCAST,MULTICAST> mtu 1500 qdisc noop state DOWN mode DEFAULT group default qlen 1000
    link/ether b4:96:91:e3:ba:0b brd ff:ff:ff:ff:ff:ff
    altname enp13s0f1
9: p2p2: <BROADCAST,MULTICAST> mtu 1500 qdisc noop state DOWN mode DEFAULT group default qlen 1000
    link/ether b4:96:91:b4:4d:09 brd ff:ff:ff:ff:ff:ff
    vf 0    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 1    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 2    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 3    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 4    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    vf 5    link/ether 00:00:00:00:00:00 brd ff:ff:ff:ff:ff:ff, spoof checking on, link-state auto, trust off
    altname enp81s0f1
10: p4p1: <NO-CARRIER,BROADCAST,MULTICAST,UP> mtu 1500 qdisc mq state UP mode DEFAULT group default qlen 1000
    link/ether b4:96:91:b4:4d:08 brd ff:ff:ff:ff:ff:ff
```

Modify configMap as following:

```
vi ~ /go/src/github.com/intel/sriov-network-device-plugin/deployments
```

```

apiVersion: v1
kind: ConfigMap
metadata:
  name: sriovdp-config
  namespace: kube-system
data:
  config.json: |
    {
      "resourceList": [
        {
          "resourceName": "intel_sriov_odu",
          "selectors": {
            "vendors": ["8086"],
            "devices": ["1889"],
            "drivers": ["enp81s0f0"]
          }
        },
        {
          "resourceName": "intel_sriov_oru",
          "selectors": {
            "vendors": ["8086"],
            "devices": ["1889"],
            "drivers": ["vfio-pci"],
            "pfNames": ["enp81s0f1"]
          }
        },
        {
          "resourceName": "intel_fec_5g",
          "deviceType": "accelerator",
          "selectors": {
            "vendors": ["8086"],
            "devices": ["0d5d"]
          }
        },
        {
          "resourceName": "mlnx_sriov_rdma",
          "selectors": {
            "vendors": ["15b3"],
            "devices": ["1017"],
            "drivers": ["mlx5_core"],
            "isRdma": true
          }
        }
      ]
    }

```

```
kubectl create -f configMap.yaml
```

Modify /var/flexran/build/docker/flexran_testmac_mode.yaml according to your specs:

```
kubectl create -f flexran_testmac_mode.yaml
```

```

XR12-B:/var/flexran/build/docker # kubectl get pods
NAME             READY   STATUS    RESTARTS   AGE
flexran-binary-release   2/2     Running   0          110s
testpod1         1/1     Running   0          16h

```

5.5 Testing FlexRAN™ Timer Mode in Containers

To demonstrate simple functionality:

In the 1st terminal run:

```
kubectl exec -it flexran-binary-release -c flexran-l1app -- bash  
Start l1.sh -e
```

In the 2nd terminal run:

```
kubectl exec -it flexran-binary-release -c flexran-testmac -- bash
```



Note

Make sure that your dpdk directory mapped in the yaml file.

Other tests such as xRAN Mode and a Helm Chart test can be run as well as described in section 5.2 and 5.3 of Intel document 575834-15.0 [Installation Guide Software Release v22.07]

As a simplified solution, a pre-configured Intel® FlexRAN™ helm chart as well as all required CNI plugins, can be posted on Rancher Marketplace to simplify deployment at a large scale.

6 Summary

Building, testing, and deploying a properly configured Intel® FlexRAN™ implementation can show the benefits of VNFs and vRAN with Intel® Xeon® Scalable Processors and Intel® Advanced Vector Extensions.

SUSE provides all the elements for an open-source, enterprise-grade, software-defined stack for cloud-native orchestration and management. SUSE Linux Enterprise (with Real Time extensions), SUSE Linux Enterprise Micro Real Time, Rancher Kubernetes Engine v2 (RKE2) and Rancher Management were used and illustrated as key ingredients to simplify the deployment of Intel® FlexRAN™.

7 Reference

- [https://github.com/intel/FlexRAN ↗](https://github.com/intel/FlexRAN)
- [https://www.intel.com/content/www/us/en/developer/videos/how-radio-access-network-is-being-virtualized-and-the-role-of-flexran.html?wapkw=FlexRan ↗](https://www.intel.com/content/www/us/en/developer/videos/how-radio-access-network-is-being-virtualized-and-the-role-of-flexran.html?wapkw=FlexRan)
- [https://www.intel.com/content/www/us/en/developer/topic-technology/edge-5g/tools/flexran.html?wapkw=FlexRan ↗](https://www.intel.com/content/www/us/en/developer/topic-technology/edge-5g/tools/flexran.html?wapkw=FlexRan)
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