TECHNOLOGY GUIDE

Intel Corporation

Intel® Speed Select Technology (Intel® SST) – Performance Enhancements for 3rd Gen Intel® Xeon® Scalable Processor

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1 Introduction

Cloud service providers deliver a common group of configurable fundamental computing resources (for example, compute, storage, and network) to their users. With a growing number of multi-geo users, compute loads are spread throughout the day, allowing for increased equipment utilization.

With such a diversity of users and tenants, it becomes a challenge. An important question is how to ensure that a user or a group of users do not adversely affect other tenants in terms of performance.

Based on International Energy Agency research, data centers account for about 1% of global electricity demand.[1] With the increasing expansion of enterprise and cloud data center facilities, they are becoming a sizable part of the worldwide energy consumption. Global data center electricity demand in 2019 was around 200 TWh, or around 0.8% of global final electricity demand.[2]

Since 2010, the number of internet users worldwide has doubled while global internet traffic has grown 12-fold. International internet traffic surged by almost 40% between February and mid-April 2020 during the height of COVID-19 containment measures, driven by growth in video streaming, video conferencing, online gaming, and social networking.[3] Data centers must consider performance optimization along with being cognizant of power consumption.

Intel® Speed Select Technology (Intel® SST) is designed to address both performance and power consumption of a CPU and system power for a specific workload, such as heterogenous workloads like Network Function Virtualization (NFV) infrastructure.

This document is part of the Network Transformation Experience Kit, which is available at https://networkbuilders.intel.com/network-technologies/network-transformation-exp-kits.

[1] Data Centres and Data Transmission Networks https://www.iea.org/reports/data-centres-and-data-transmission-networks

[2] IEA analysis based on Masanet, E. et al. (2020). Recalibrating global data center energy-use estimates, Science, 367(6481), 984-986, https://doi.org/10.1126/science.aba3758.

[3] Sandvine (2020). The Global Internet Phenomena Report. https://www.sandvine.com/hubfs/Sandvine_Redesign_2019/Downloads/2020/Phenomena/COVID%20Internet%20Phenomena%20Report%2020200507.pdf.

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Document Revision History

REVISION	DATE	DESCRIPTION
001	December 2021	Initial release.

1.1 Terminology

Table 1. Terminology

ABBREVIATION	DESCRIPTION
BKC	Best Known Configuration
BOM	Bill of Material
CLOS	Class of Service
CPU	Central Processing Unit
DPDK	Data Plane Development Kit
DUT	Device Under Test
Intel® AVX	Intel® Advanced Vector Extensions (Intel® AVX)
Intel® SST-BF	Intel Speed Select Technology - Base Frequency (Intel® SST-BF)
Intel® SST-CP	Intel Speed Select Technology – Core Power (Intel® SST-CP)
Intel® SST-PP	Intel Speed Select Technology – Performance Profile (Intel® SST-PP)
Intel® SST-TF	Intel Speed Select Technology – Turbo Frequency (Intel® SST-TF)
I/O	Input/Output
NFV	Network Function Virtualization
NFVi	Network Function Virtualization Infrastructure
NIC	Network Interface Card
OVS	Open vSwitch
Pktgen	Ethernet Packet Generator
PTU	Power Thermal Utility
SLA	Service Level Agreement
TCO	Total Cost of Ownership
TDP	Thermal Design Power
VM	Virtual Machine
VNF	Virtual Network Function

1.2 Reference Documentation

Table 2. Reference Documents

REFERENCE	SOURCE
Data Centres and Data Transmission Networks	https://www.iea.org/reports/data-centres-and-data-transmission-networks
Recalibrating global data center energy-use estimates	https://doi.org/10.1126/science.aba3758
The Global Internet Phenomena Report COVID-19 Spotlight	https://www.sandvine.com/hubfs/Sandvine_Redesign_2019/Downloads/2020/Phenomena/COVID%20Internet%20Phenomena%20Report%2020200507.pdf
Case Study of Scaled-Up SKT* 5G MEC Reference Architecture	https://www.intel.co.jp/content/dam/www/public/us/en/documents/white-papers/case-study-of-scaled-up-skt-5g-mec-reference-architecture.pdf
DPDK testpmd Introduction	https://doc.dpdk.org/guides/testpmd_app_ug/intro.html

2 Overview

Intel Speed Select Technology, for granular control over CPU power and performance on 3rd Gen Intel® Xeon® Scalable processors, is a collection of features that aims to improve performance and optimize Total Cost of Ownership (TCO) by providing more control over CPU performance.[4]

- Intel Speed Select Technology - Performance Profile (Intel SST-PP)
  Intel SST-PP helps improve server utilization and reduce server qualification test costs by enabling configuration of a single server (not several) to match fluctuating workloads. One flexible server, multiple "configurations-optimized", TCO is the natural result.
- Intel Speed Select Technology - Base Frequency (Intel SST-BF)
  Intel SST-BF lets the user control base frequency. If some critical workload threads demand constant high guaranteed performance, then this feature can be used to execute the threads at higher base frequency on specific sets of CPUs (high priority CPUs) at the cost of lower base frequency (low priority CPUs) on other CPUs.
- Intel Speed Select Technology - Turbo Frequency (Intel SST-TF)
  Intel SST-TF provides the ability to assign prioritization on turbo frequency to specific cores. By using this feature, some cores can be configured to get higher turbo frequency by designating them as high priority at the cost of lower or no turbo frequency on the low priority cores.
- Intel Speed Select Technology - Core Power (Intel SST-CP)
  Intel SST-CP allows users to define per core priority. This technology provides a mechanism to distribute power among cores when there is a power constrained scenario.

Utilizing Intel SST-BF, Intel SST-CP, and Intel SST-TF may deliver CPU power and performance to mission-critical cores and deliver expected SLA without being impacted by what is going on with other lower priority cores.

Utilizing Intel SST-PP with Intel SST-CP may control the power utilized by NFV power-hungry process, cutting its power consumption during idle time.

3 Test Setup

The following figure shows the overall structure of the Device Under Test (DUT) setup and systems used to exercise various traffic profiles for each test.

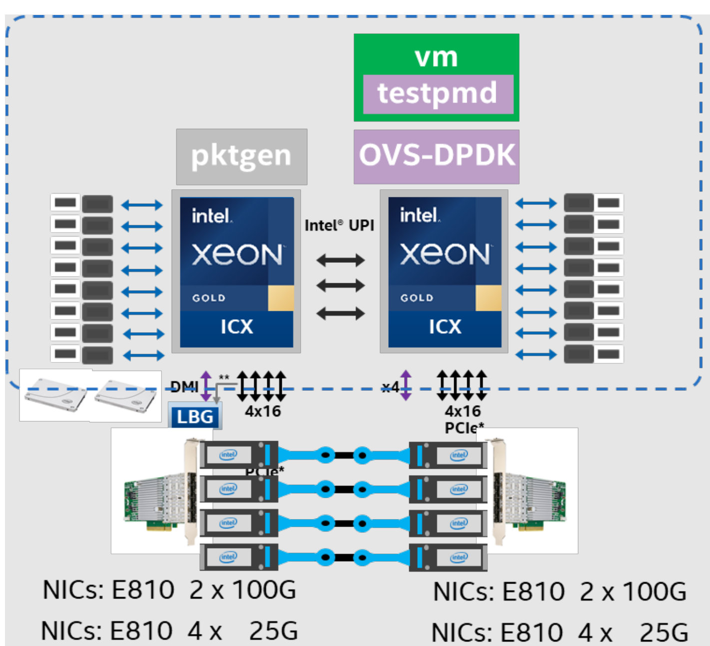

Figure 1. Test Setup and Systems

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[4] Case Study of Scaled-Up SKT* 5G MEC Reference Architecture https://www.intel.co.jp/content/dam/www/public/us/en/documents/white-papers/case-study-of-scaled-up-skt-5g-mec-reference-architecture.pdf

- Environment: The system CPU sockets are separated into two segments. CPU1 serves as a DUT running critical and noisy neighbor workload. CPU0's sole purpose is to generate traffic and collect the packets forwarded by the DUT (CPU1).
- Workload:
  - Critical Workload: The critical workload focuses on network transformation. It consists of Open vSwitch as Network Function Virtualization Infrastructure (NFVi) supporting traffic from 100 Gbps Network Interface Cards (NICs) ports to virtual ports in the VM. Within the VM, Data Plane Development Kit (DPDK) testpmd serves as a very basic Virtual Network Function (VNF), processing the packet and sending it back out to the physical ports.
  - Noisy Neighbor Workload: The noisy neighbor workload is the Power Thermal Utility (PTU) running Intel® Advanced Vector Extensions 512 (Intel® AVX-512) at CPU power level 100%. PTU for Intel® 3rd Gen Intel® Xeon® Scalable processor is intended for thermal and power delivery testing. It is used here to provide accurate stress on low priority CPU cores.

The following are the hardware and software configuration BOMs:

Table 3. Hardware Configuration

COMPONENT	DESCRIPTION
Platform	Intel® Server System M50CYP2U LUC210400141
# Nodes	1
# Sockets	2
CPU	Intel® Xeon® Platinum 8360Y @ (36 C 2.4 GHz 250 W)
Cores/socket, Threads/socket	36 cores / 72 threads
Microcode	0D000280
BIOS version	BIOS = SE5C620.86B.01.01.1003.2106150155
BMC	2.81
CPLD	V3p3
AEP FW version – for example, 5336	N/A
System DDR Mem Config: slots per socket / cap / speed / rank	64 GB (4x 16 GB DDR4, 3200 MHz)
Total Memory/Node (DDR, DCPMM)	64 G
Storage - boot	1x Intel® 240 G SSD
NIC	4x25 GB Intel® Ethernet Network Connection E810, Network speed: 25 GbE

Table 4. Software Configuration

COMPONENT	DESCRIPTION
OS	Ubuntu 20.10
Kernel	5.8.0-25-generic
Compiler	gcc version 10.2.0 (Ubuntu 10.2.0-13ubuntu1)
DPDK	dpdk-stable-19.11.3
Pktgen	pktgen-19.12.0
Open vSwitch	openvswitch-2.13.0
Qemu	qemu-2.12.1
Intel Speed Select	Version v1.7

Table 5. BIOS Configuration

COMPONENT	DESCRIPTION
HT	ON
Turbo	ON

COMPONENT	DESCRIPTION
Intel SpeedStep®	Enabled
Power management	C6 enabled
Sub-NUMA Clustering (SNC)	OFF
Prefetcher	ON
Intel SpeedStep® (P-States)	Enable
Hardware PM State Control - Hardware P-States	Native Mode with No Legacy Support
Intel SST-PP	Base
Dynamic Intel SST-PP	Enable
Configure Intel SST-BF	Enable
Frequency Prioritization - Running Average Power Limit (RAPL) Prioritization	Enable

Table 6. Environment Configuration

COMPONENT	DESCRIPTION
Open vSwitch	4 cores for PMDs • 2 cores for 2 x NICs port • 2 cores for 2 x vHost
VM	3 cores • testpmd 1 core
Pktgen	5 cores RFC2889 Pkt size = 256 bytes

4 Test Results

To demonstrate the benefit of deploying a system with Intel SST, during July 2021 we tested an NFVi setup with Open vSwitch. It provides the network plumbing between physical NICs to virtual I/O NICs in the VM, and the VMs running testpmd[5] as VNF. Both NFVi Open vSwitch and VNF VMs testpmd are categorized as critical tasks, and packet forwarding performances are collected. We conducted various test scenarios to highlight the benefits of Intel SST features, and these are outlined below.

4.1 Zero Performance Impact from Noisy Neighbors

The purpose of the following tests is to show that utilizing Intel SST-BF, Intel SST-CP, and Intel SST-TF, the performance of critical tasks is improved with each feature by delivering more frequency (power) to critical tasks.

1. Critical Only: This is a control test with only the critical task running. Other cores are idle to highlight the performance when the system only handles NFVi + VNF critical tasks.
2. Busy: While NFVi + VNF critical tasks are running, we deploy PTU Intel AVX-512 test on all of the remaining CPU cores as noisy neighbors, without any Intel SST feature enabled.
3. Intel SST-BF: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all of the remaining CPU cores, enable Intel SST-BF on the system.
4. Intel SST-CP: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all of the remaining CPU cores, enable Intel SST-CP on the system, allowing critical cores to run at max frequency but limiting the PTU's cores to 800 MHz.
5. Intel SST-TF: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all of the remaining CPU cores, the system turns on Intel SST-CP, allowing critical cores to run at max frequency but limiting the PTU's cores to 800 MHz. Intel SST-TF is also turned on, giving a boost to critical cores.

[5] DPDK TestPMD introduction https://doc.dpdk.org/guides/testpmd_app_ug/intro.html

Table 7. Test Scenarios - Zero Performance Impact from Noisy Neighbors

TEST SCENARIO	STATE	TRAFFIC	HIGH PRIORITY CORE	LOW PRIORITY CORE	HIGH PRIORITY CRITICAL WORKLOAD	LOW PRIORITY NOISY NEIGHBOR WORKLOAD
1. Critical Only	SST-PP0, All core turbo ON	On	5 cores	31 cores	OVS, VM testpmd	idle
2. Busy	SST-PP0, All core turbo ON	On	5 cores	31 cores	OVS, VM testpmd	PTU Intel AVX-512
3. Intel SST-BF	SST-PP0, All core turbo OFF, Intel SST-BF ON	On	5 cores	31 cores	OVS, VM testpmd	PTU Intel AVX-512
4. Intel SST-CP	SST-PP0, All core turbo ON, Intel SST-BF OFF, Intel SST-CP ON	On	5 cores Intel SST-CP CLOS0 - Min = 0 MHz - Max = unlimited	31 cores Intel SST-CP CLOS3 - Min = 800 MHz - Max = 800 MHz	OVS, VM testpmd	PTU Intel AVX-512
5. Intel SST-TF	SST-PP0, All core turbo ON, Intel SST-BF OFF, SST CP ON, Intel SST-TF ON	On	5 cores Intel SST-CP CLOS0 - Min = 0 MHz - Max = unlimited	31 cores Intel SST-CP CLOS3 - Min = 800 MHz - Max = 800 MHz	OVS, VM testpmd	PTU Intel AVX-512

4.1.1 Throughput Performance

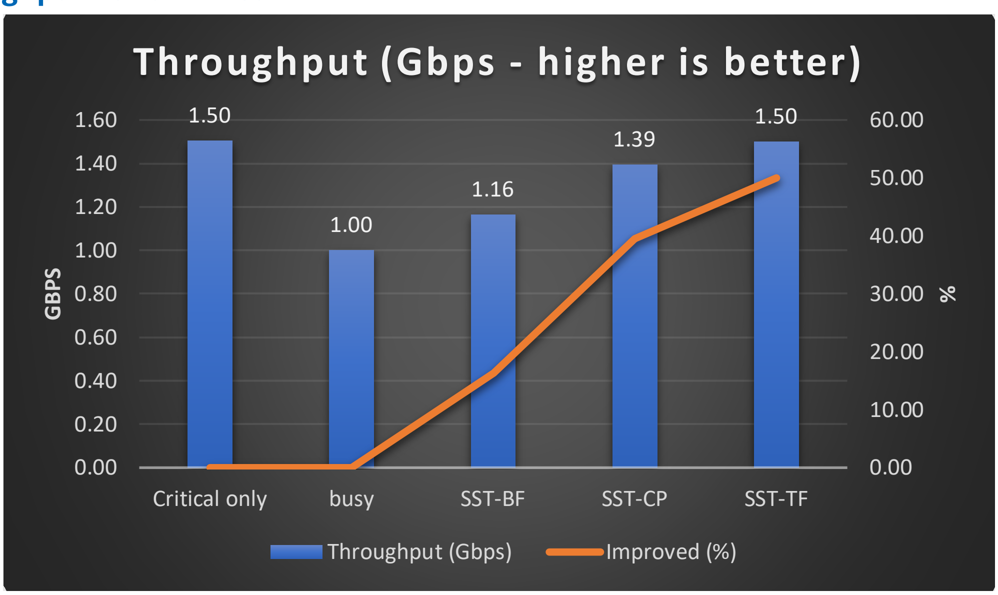


Figure 2. Throughput Performance for Test Scenarios – Zero Performance Impact from Noisy Neighbors

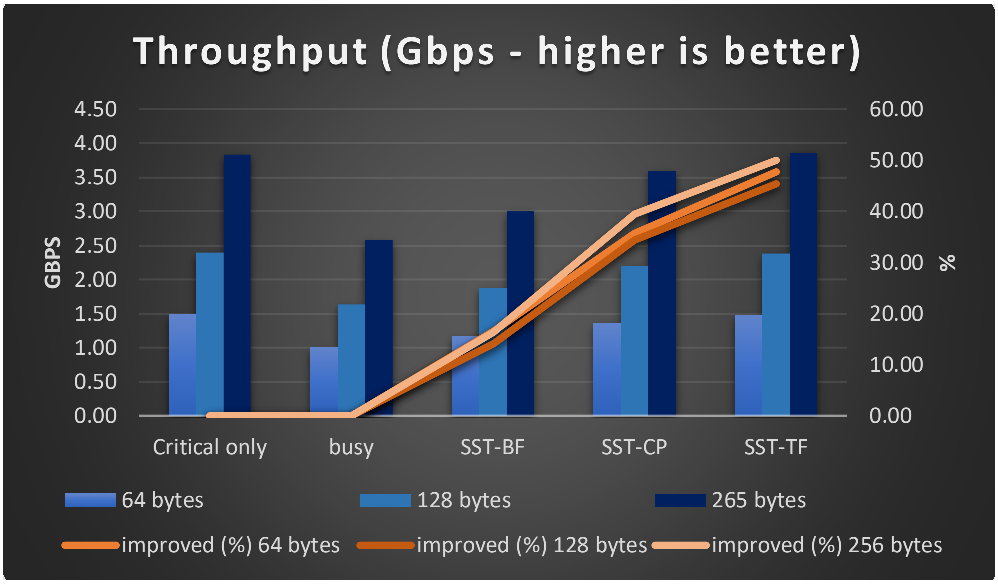


Figure 3. Throughput Performance using 64-, 128-, and 256-byte Packets for Test Scenarios – Zero Performance Impact from Noisy Neighbors

4.1.2 Summary

In this scenario, when the Intel SST features listed are enabled, we regained ALL performance degradation due to noisy neighbor interference. Intel SST-BF can provide "up to" approximately 16% improved critical performance. Intel SST-CP can provide "up to" approximately 39% performance improvement. Intel SST-TF can provide "up to" approximately 51% performance improvement.

4.2 CPU Power Reduction

There are situations where network traffic can be low or idle, and it is possible to use Intel SST-CP to limit or reduce the performance or power of a critical task. We use the following tests to measure the power reduction after applying Intel SST-CP.

1. Critical Only: Four cores running open Open vSwitch and one core running testpmd in a VM, but no traffic flowing across these cores.
2. Critical + Traffic: Four cores running open Open vSwitch and one core running testpmd in a VM, while traffic flows across these cores.
3. Intel SST-CP: Limit core power of high priority cores, limiting polling I/O threads in NFVi + VNF critical tasks.

Table 8. Test Scenarios – CPU Power Reduction

TEST SCENARIO	STATE	TRAFFIC	HIGH PRIORITY CORE	LOW PRIORITY CORE	HIGH PRIORITY CRITICAL WORKLOAD	LOW PRIORITY NOISY NEIGHBOR WORKLOAD
1. Critical Only	SST-PP0, All core turbo ON	Off	5 cores	31 cores	OVS, VM testpmd	idle
2. Critical + Traffic	SST-PP0, All core turbo ON	On	5 cores	31 cores	OVS, VM testpmd	idle
3. Intel SST-CP	SST-PP0, All core turbo ON, Intel SST-BF OFF, Intel SST-CP ON	On	5 cores, Intel SST-CP CLOS0 - Min = 800 MHz - Max = 800 MHz	31 cores, Intel SST-CP CLOS3 - Min = 800 MHz - Max = 800 MHz	OVS, VM testpmd	idle

4.2.1 CPU Power Saving

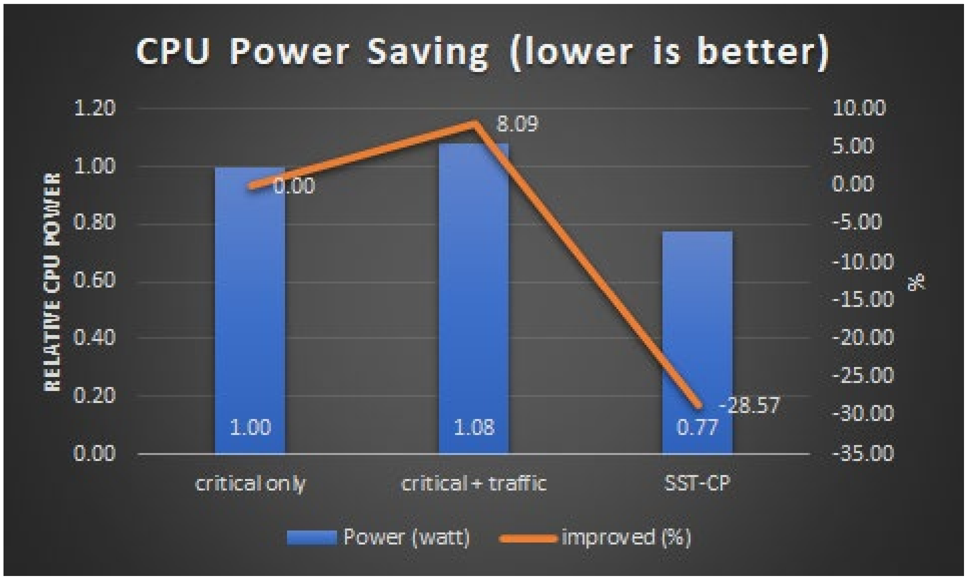


Figure 4. Power Saving Across Test Scenarios – CPU Power Reduction

4.2.2 Summary

In this scenario, critical workload is close to three times idle state's power, with and without traffic flowing. Intel SST-CP can help reduce system power down to 28% of power.

4.3 Full Load Power Reduction with Intel SST-PP

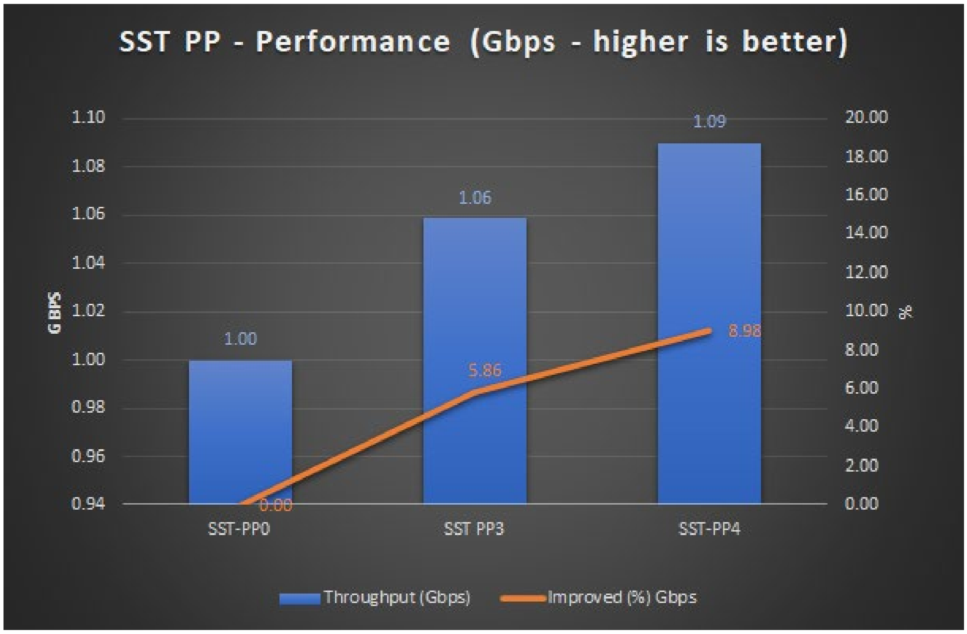
If you wish to reduce data center and server power consumption, Intel SST-PP can be used to deactivate cores (power off), and Intel SST-CP can be used to reduce the frequency or power of active cores. All of this is done while maintaining, and in certain scenarios improving, the performance or frequency of critical tasks.

1. Intel SST-PP0: While NFVi + VNF critical tasks are running, we deploy PTU Intel AVX-512 test on all remaining CPU cores, without any Intel SST feature enabled.
2. Intel SST-PP3: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all remaining CPU cores, the system switches to Intel SST-PP profile 3.
3. Intel SST-PP4: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all remaining CPU cores, the system switches to Intel SST-PP profile 4.

Table 9. Test Scenarios – Full Load Power Reduction with Intel SST-PP

TEST SCENARIO	STATE	TRAFFIC	HIGH PRIORITY CORE	LOW PRIORITY CORE	HIGH PRIORITY CRITICAL WORKLOAD	LOW PRIORITY NOISY NEIGHBOR WORKLOAD
SST-PP0	SST-PP0, All core turbo ON	On	5 cores	31 cores	OVS, VM testpmd	PTU Intel AVX-512
SST-PP3	SST-PP3, All core turbo ON	On	5 cores	27 cores	OVS, VM testpmd	PTU Intel AVX-512
SST-PP4	SST-PP4, All core turbo ON	On	5 cores	19 cores	OVS, VM testpmd	PTU Intel AVX-512

4.3.1 Performance and Power Saving



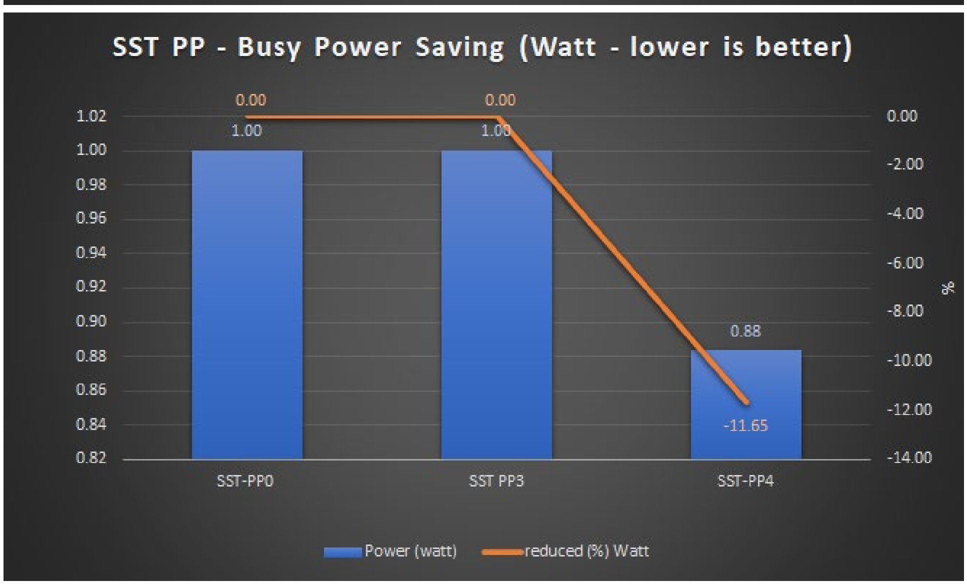


Figure 5. Performance and Power Results for Intel SST-PP Profile – Full Load Power Reduction

4.3.2 Summary

In this scenario, critical workload gains approximately 8% performance utilizing Intel SST-PP. Approximately 11% power (watt) can be reduced using Intel SST-PP.

4.4 Full Load Power Reduction with Intel SST-PP and Intel SST-CP

A small tweak to the test scenario in Section 4.3, we use Intel SST-PP to deactivate cores (power off) and alter CPU SKU's Thermal Design Power (TDP). Intel SST-CP is used here to reduce the frequency/power of active cores hosting noisy neighbor task.

1. SST-PP0: While NFVi + VNF critical tasks are running, we deploy PTU Intel AVX-512 test on all remaining CPU cores, without any SST feature enabled.
2. SST-PP0 + Intel SST-CP: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all remaining CPU cores, the system turns on Intel SST-CP, allowing critical cores to run at max frequency but limiting PTU's cores to 800 MHz.
3. SST-PP3 + Intel SST-CP: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all remaining CPU cores, from SST-PP3 the system turns on Intel SST-CP, allowing critical cores to run at max frequency but limiting PTU's cores to 800 MHz.

4. SST-PP4 + Intel SST-CP: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all remaining CPU cores, from SST-PP4 the system turns on Intel SST-CP, allowing critical cores to run at max frequency but limiting PTU's cores to 800 MHz

Table 10. Test Scenarios – Full Load Power Reduction with Intel SST-PP and Intel SST-CP

TEST SCENARIO	STATE	TRAFFIC	HIGH PRIORITY CORE	LOW PRIORITY CORE	HIGH PRIORITY CRITICAL WORKLOAD	LOW PRIORITY NOISY NEIGHBOR WORKLOAD
SST-PP0	SST-PP0, All core turbo ON	On	5 cores	31 cores	OVS, VM testpmd	PTU Intel AVX-512
SST-PP0 + Intel SST-CP	SST-PP0, All core turbo ON, Intel SST-BF OFF, Intel SST-CP ON	On	5 cores, Intel SST-CP CLOS0 - Min = 0 MHz - Max = unlimited	31 cores, Intel SST-CP CLOS3 - Min = 800 MHz - Max = 800 MHz	OVS, VM testpmd	PTU Intel AVX-512
SST-PP3 + Intel SST-CP	SST-PP3, All core turbo ON, Intel SST-BF OFF, Intel SST-CP ON	On	5 cores, Intel SST-CP CLOS0 - Min = 0 MHz - Max = unlimited	27 cores, Intel SST-CP CLOS3 - Min = 800 MHz - Max = 800 MHz	OVS, VM testpmd	PTU Intel AVX-512
SST-PP4 + Intel SST-CP	SST-PP4, All core turbo ON, Intel SST-BF OFF, Intel SST-CP ON	On	5 cores, Intel SST-CP CLOS0 - Min = 0 MHz - Max = unlimited	19 cores, Intel SST-CP CLOS3 - Min = 800 MHz - Max = 800 MHz	OVS, VM testpmd	PTU Intel AVX-512

4.4.1 Performance and Power

Figure 6. Performance and Power Results for Intel SST-PP Profile + Intel SST-CP

4.4.2 Summary

In this scenario, critical workload gains approximately 46% performance utilizing Intel SST-PP in conjunction with Intel SST-CP. Approximately 27% power (watt) can be reduced using Intel SST-PP in conjunction with Intel SST-CP.

4.5 Full Load Power Reduction with Intel SST-PP, Intel SST-CP, and Intel SST-TF

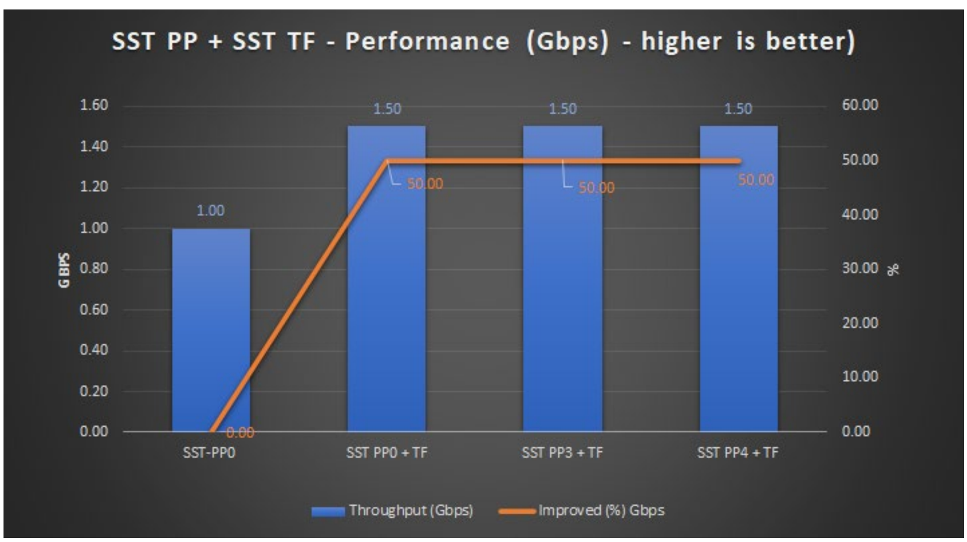
Enhancing from the test scenario in Section 4.4, we enable Intel SST-TF on top of Intel SST-PP to deactivate cores (power off) and alter CPU SKU's TDP. Intel SST-CP is used here to reduce the frequency/power of active cores hosting noisy neighbor task. Intel SST-TF increases power consumption slightly. The power is used to boost critical workload performance.

1. SST-PP0: While NFVi + VNF critical tasks are running, we deploy PTU Intel AVX-512 test on all remaining CPU cores, without any Intel SST feature enabled.
2. SST-PP0 + Intel SST-CP: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all remaining CPU cores, the system turns on Intel SST-CP, allowing critical cores to run at max frequency but limiting PTU's cores to 800 MHz.
3. SST-PP3 + Intel SST-CP: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all remaining CPU cores, from SST-PP3 the system turns on Intel SST-CP, allowing critical cores to run at max frequency but limiting PTU's cores to 800 MHz.
4. SST-PP4 + Intel SST-CP: While NFVi + VNF critical tasks are running, and PTU Intel AVX-512 is running on all remaining CPU cores, from SST-PP4 the system turns on Intel SST-CP, allowing critical cores to run at max frequency but limiting PTU's cores to 800 MHz.

Table 11. Test Scenarios – Full Load Power Reduction with SST-PP, SST-CP, and SST-TF

TEST SCENARIO	STATE	TRAFFIC	HIGH PRIORITY CORE	LOW PRIORITY CORE	HIGH PRIORITY CRITICAL WORKLOAD	LOW PRIORITY NOISY NEIGHBOR WORKLOAD
SST-PP0	SST-PP0, All core turbo on	On	5 cores	31 cores	OVS, VM testpmd	PTU Intel AVX-512
SST-PP0 + Intel SST-TF	SST-PP0, All core turbo on, Intel SST-BF OFF, Intel SST-CP ON, Intel SST-TF ON	On	5 cores, Intel SST-CP CLOS0 - Min = 0 MHz - Max = unlimited	31 cores, Intel SST-CP CLOS3 - Min = 800 MHz - Max = 800 MHz	OVS, VM testpmd	PTU Intel AVX-512
SST-PP3 + Intel SST-TF	SST-PP3, All core turbo on, Intel SST-BF OFF, Intel SST-CP ON, Intel SST-TF ON	On	5 cores, Intel SST-CP CLOS0 - Min = 0 MHz - Max = unlimited	19 cores, Intel SST-CP CLOS3 - Min = 800 MHz - Max = 800 MHz	OVS, VM testpmd	PTU Intel AVX-512
SST-PP4 + Intel SST-TF	SST-PP4, All core turbo on, Intel SST-BF OFF, Intel SST-CP ON, Intel SST-TF ON	On	5 cores, Intel SST-CP CLOS0 - Min = 0 MHz - Max = unlimited	11 cores, Intel SST-CP CLOS3 - Min = 800 MHz - Max = 800 MHz	OVS, VM testpmd	PTU Intel AVX-512

4.5.1 Performance and Power



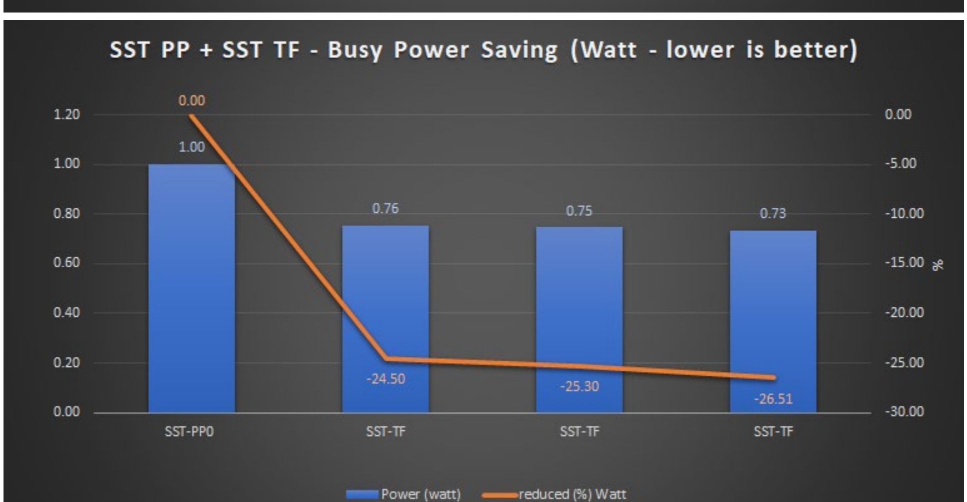


Figure 7. Performance and Power Results for Intel SST-PP Profile + Intel SST-CP + Intel SST-TF

4.5.2 Summary

In this scenario, critical workload gains approximately 50% performance utilizing Intel SST-PP in conjunction with Intel SST-TF. Approximately 26% power (watt) can be reduced using Intel SST-PP in conjunction with Intel SST-TF.

5 Conclusion

From actual test experiments, we show that utilizing Intel Speed Select Technology delivers the following benefits:

- Traffic forwarding performance increases by approximately 16% to approximately 51% utilizing Intel SST-BF, Intel SST-CP, and Intel SST-TF, while the CPU is fully loaded with critical workload and noisy neighbors. Packet forwarding performance returns to the same level of performance without noisy neighbor interference.
- During idle periods, Intel SST-CP can reduce power about 20%, thus reducing the impact of mission-critical tasks, for example NFVi and VNF, that constantly poll and consume CPU power even though there is no incoming traffic.
- Various Intel SST-PP profiles deliver critical workload performance improvements. When combined with Intel SST-CP and Intel SST-TF, the performance increased by approximately 50% per single CPU socket.

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