



Bloombase StoreSafe and Broadcom NetXtreme P2100G NIC Integration Guide for Data- at-Rest Encryption

June 2022



Executive Summary

Broadcom NetXtreme P2100G Network Interface Card (NIC) has been validated by Bloombase InteropLab to run with Bloombase StoreSafe Intelligent Storage Firewall. This document describes the steps carried out to integrate Broadcom NetXtreme P2100G NIC with Bloombase StoreSafe Intelligent Storage Firewall software appliance on Dell PowerEdge Intel Xeon Server to deliver high-bandwidth, low-latency application-transparent storage encryption using Post-Quantum Cryptography (PQC) technologies for mission critical applications. Client host system Red Hat Enterprise Linux (RHEL) 8.6 has been tested with the Broadcom NetXtreme P2100G NIC and Bloombase StoreSafe data-at-rest encryption solution to secure storage backend via Non-Volatile Memory Express (NVMe) over RDMA over Converged Ethernet (NVMe/RoCE) and Non-Volatile Memory Express (NVMe) over Transmission Control Protocol (TCP) (NVMe/TCP) network storage protocols powered by Red Hat Enterprise Linux (RHEL) 8.6 with Intel Solid State Drives (SSDs).

Information in this document, including URL and other Internet Web site references, is subject to change without notice. Unless otherwise noted, the example companies, organizations, products, people and events depicted herein are fictitious and no association with any real company, organization, product, person or event is intended or should be inferred. Complying with all applicable copyright laws is the responsibility of the user. Without limiting the rights under copyright, no part of this document may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise), or for any purpose, without the express written permission of Bloombase, Inc.

Bloombase, Inc. may have patents, patent applications, trademarks, copyrights, or other intellectual property rights covering subject matter in this document. Except as expressly provided in any written license agreement from Bloombase, Inc, the furnishing of this document does not give you any license to these patents, trademarks, copyrights, or other intellectual property.

This document is the property of Bloombase, Inc. No exploitation or transfer of any information contained herein is permitted in the absence of an agreement with Bloombase, Inc, and neither the document nor any such information may be released without the written consent of Bloombase, Inc.

© 2022 Bloombase, Inc.

Bloombase, Keyparc, Spitfire, StoreSafe are either registered trademarks or trademarks of Bloombase in the United States and/or other countries.

Broadcom and NetXtreme are trademarks of Broadcom and/or its affiliated companies.

The names of actual companies and products mentioned herein may be the trademarks of their respective owners.

Document No.: BLBS-TN - Bloombase StoreSafe Broadcom NetXtreme P2100G NIC Integration Guide - USLET-EN-R1

Table of Contents

Table of Contents	3
Purpose and Scope	6
Assumptions	7
Infrastructure	8
Setup	8
Storage Encryption	10
Storage System	10
Storage Host	10
Networking	10
Configuration Overview	11
Network Configuration	11
Ethernet Switch Configuration	11
Direct Attach Copper (DAC) Cable	12
100G Network Interface Card (NIC)	13
Broadcom NetXtreme P2100 NIC Installation and Configuration	13
NVMe over Fabrics (NVMe-oF) Storage Backend	14
Solid State Drive (SSD)	14
Linux NVMe-oF Storage Target	14
Bloombase StoreSafe Intelligent Storage Firewall	15
Broadcom NetXtreme P2100G NIC and Bloombase StoreSafe Integration	16
Key Generation	17
Bloombase StoreSafe Data-at-Rest Encryption for NVMe/RoCE and NVMe/TCP Configuration	19
Storage Client	21
Test Cases	22
Functional Tests for Data-at-Rest Encryption over NVMe/RoCE	22
Read Test	23
Write Test	24
Functional Tests for Data-at-Rest Encryption over NVMe/TCP	25
Read Test	26
Write Test	28
Throughput Tests for Data-at-Rest Encryption over NVMe/RoCE	29
Read Test	29
Write Test	29
Throughput Tests for Data-at-Rest Encryption over NVMe/TCP	30
Read Test	30
Write Test	30
Latency Tests for Data-at-Rest Encryption over NVMe/RoCE	31
Read Test	31
Write Test	31
Latency Tests for Data-at-Rest Encryption over NVMe/TCP	32

Read Test	32
Write Test	33
Throughput and Latency Comparisons of Bloombase StoreSafe Data-at-Rest Encryption using Broadcom NetXtreme P2100G vs Marvell FastLinQ QL45611HLCU	33
Throughput Test Results	33
Latency Test Results	34
 Conclusion	 35
 Disclaimer	 37
 Acknowledgement	 38
 Reference	 39
 Appendix A – Bloombase StoreSafe with Marvell FastLinQ QL45611HLCU	 40
Throughput Tests for Data-at-Rest Encryption over NVMe/RoCE	40
Read Test	40
Write Test	40
Throughput Tests for Data-at-Rest Encryption over NVMe/TCP	41
Read Test	41
Write Test	41
Latency Tests for Data-at-Rest Encryption over NVMe/RoCE	41
Read Test	41
Write Test	42
Latency Tests for Data-at-Rest Encryption over NVMe/TCP	42
Read Test	42
Write Test	43

Purpose and Scope

This document describes the steps necessary to integrate Broadcom NetXtreme P2100G NIC with Bloombase StoreSafe Intelligent Storage Firewall to deliver agentless, transparent encryption security of traditional storage systems and next-generation storage services for mission-critical applications. Specifically, we cover the following topics:

- Install and configure Bloombase StoreSafe Intelligent Storage Firewall software appliance
- Integrate Bloombase StoreSafe Intelligent Storage Firewall with Broadcom NetXtreme P2100G NIC
- Integrate Red Hat Enterprise Linux (RHEL) 8.6 client host system and storage backend powered by Red Hat Enterprise Linux (RHEL) 8.6 with Bloombase StoreSafe Intelligent Storage Firewall to demonstrate how high-bandwidth, low-latency, application-transparent data encryption could be achieved for NVMe/RoCE and NVMe/TCP storage protocols
- Functional and performance testing of data-at-rest encryption over NVMe/RoCE and NVMe/TCP protocols delivered by Bloombase StoreSafe Intelligent Storage Firewall with Broadcom NetXtreme P2100G NIC
- Performance tests are also done on Bloombase StoreSafe Intelligent Storage Firewall installed with Marvell FastLinQ QL45611HLCU NIC as comparison

Assumptions

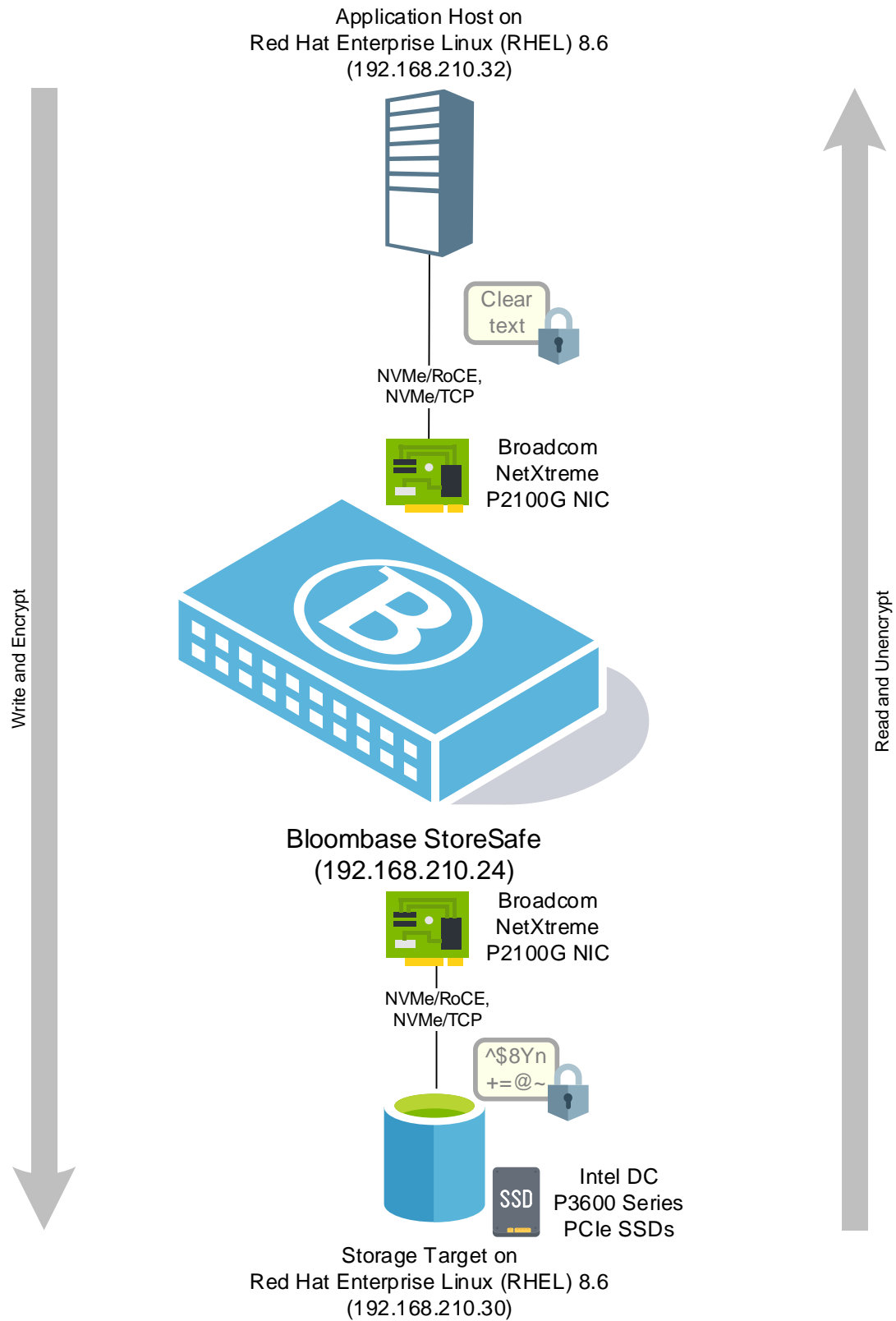
This document describes the integration of Broadcom NetXtreme P2100G NIC with Bloombase StoreSafe Intelligent Storage Firewall. It is assumed that you are familiar with operation of storage systems, and major operating systems including Linux, Microsoft Windows, IBM AIX, HP-UX and Oracle Sun Solaris. It is also assumed that you possess basic UNIX administration skills. The examples provided may require modifications before they are run under your version of operating system.

As Broadcom NetXtreme P2100G NIC is third party option to Bloombase StoreSafe Intelligent Storage Firewall data at-rest encryption security solution, you are recommended to refer to technical notes of Broadcom NetXtreme P2100G NIC for your actual use cases. We assume you have basic knowledge of storage networking and information cryptography. For specific technical product information of Bloombase StoreSafe, please refer to our website at <https://www.bloombase.com> and Bloombase SupPortal <https://supportal.bloombase.com>.

Infrastructure

Setup

The integration discussed in this guide is based on the system block diagram below:



Storage Encryption

Storage Encryption	Bloombase StoreSafe Intelligent Storage Firewall Software Appliance v3.4.9.0
Server	Dell PowerEdge T150 Server
Processor	Intel Xeon E-2378 2.6GHz processor
Memory	64 GB
Network Interface Card	Broadcom NetXtreme P2100G NIC

Storage System

Storage System	NVMe over Fabrics (NVMe-oF) storage services on Red Hat Enterprise Linux (RHEL) 8.6
Solid State Drives	Intel Solid State Drive DC P3600 Series PCIe NVMe SSDs

Storage Host

Client Host	Red Hat Enterprise Linux (RHEL) 8.6
Network Interface Card	Broadcom NetXtreme P2100G NIC

Networking

Ethernet Switch	Celestica Seastone DXo10 32-port 100GbE ONIE Switch
Cables	NVIDIA/Mellanox 100GbE QSFP28 DAC Cables

Configuration Overview

Network Configuration

Ethernet Switch Configuration

Celestica Seastone DX010 32-port 100GbE ONIE switch has been used in this integration testing.



Ports 24 and 28 of the 100Gb Ethernet switch are connected to the Broadcom NetXtreme P2100G NICs via DAC cables as shown in the SONiC console below.

```
Linux sonic 5.10.0-8-2-amd64 #1 SMP Debian 5.10.46-4 (2021-08-03) x86_64
You are on
```

```

  /-----/ \-----/ \-----/ \-----/ \-----/
 /-----/ \-----/ \-----/ \-----/ \-----/
/-----/ \-----/ \-----/ \-----/ \-----/
|-----/ \-----/ \-----/ \-----/ \-----/

```

```
-- Software for Open Networking in the Cloud --
```

```
Unauthorized access and/or use are prohibited.
All access and/or use are subject to monitoring.
```

```
admin@sonic:~$ sudo config vlan add 210
admin@sonic:~$ sudo config vlan member add -u 210 Ethernet24
admin@sonic:~$ sudo config vlan member add -u 210 Ethernet28
```

```
admin@sonic:~$ show vlan brief
```

VLAN ID	IP Address	Ports	Port Tagging	Proxy ARP	DHCP Helper Address
210		Ethernet24	untagged	disabled	
		Ethernet28	untagged		

```
admin@sonic:~$ show interfaces status
```

Interface	Lanes	Speed	MTU	FEC	Alias	Vlan	Oper	Admin	Type	Asym PFC
Ethernet0	65,66,67,68	100G	9100	rs	Eth1	trunk	down	up	N/A	N/A
Ethernet4	69,70,71,72	100G	9100	rs	Eth2	trunk	up	up	QSFP28 or later	N/A
Ethernet8	73,74,75,76	100G	9100	N/A	Eth3	trunk	down	up	N/A	N/A
Ethernet12	77,78,79,80	100G	9100	rs	Eth4	trunk	up	up	QSFP28 or later	N/A
Ethernet16	33,34,35,36	100G	9100	rs	Eth5	trunk	down	up	QSFP28 or later	N/A
Ethernet20	37,38,39,40	100G	9100	N/A	Eth6	trunk	down	up	N/A	N/A
Ethernet24	41,42,43,44	100G	9100	N/A	Eth7	trunk	up	up	QSFP28 or later	N/A
Ethernet28	45,46,47,48	100G	9100	N/A	Eth8	trunk	up	up	QSFP28 or later	N/A

```
Ethernet24: SFP EEPROM detected
  Application Advertisement: N/A
  Connector: No separable connector
  Encoding: Unspecified
  Extended Identifier: Power Class 1(1.5W max)
  Extended RateSelect Compliance: QSFP+ Rate Select Version 1
  Identifier: QSFP28 or later
  Length Cable Assembly(m): 2
  Nominal Bit Rate(100Mbs): 255
  Specification compliance:
    Extended Specification compliance: 100GBASE-CR4, 25GBASE-CR CA-25G-L or 50GBASE-CR2
with RS
  Vendor Date Code(YYYY-MM-DD Lot): 2021-12-06
  Vendor Name: FS
  Vendor OUI: 00-02-c9
  Vendor PN: Q28-PC02
  Vendor Rev: A2
  Vendor SN: G2140009608-2
```

Direct Attach Copper (DAC) Cable

NVIDIA/Mellanox 100GbE QSFP28 DAC cables have been used in this interoperability testing.



100G Network Interface Card (NIC)

Broadcom NetXtreme P2100 NIC has been used in this integration testing.



Broadcom NetXtreme P2100 NIC Installation and Configuration

Install and configure Broadcom NetXtreme P2100 NIC using automated driver installer.

```
[root@bb024 ~]# cd software/bcm_222.1.68.0/Linux/Linux_Installer/  
[root@bb024 Linux_Installer]# bash install.sh -i ens2f0np0  
Starting installation, see install.log for details
```

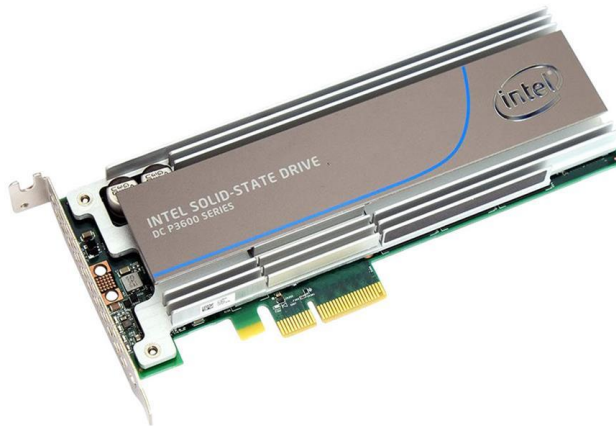
```
[root@bb024 ~]# lspci | grep Broadcom  
01:00.0 Ethernet controller: Broadcom Inc. and subsidiaries BCM57508 NetXtreme-E 10Gb/25Gb/40Gb/50Gb  
/100Gb/200Gb Ethernet (rev 11)  
01:00.1 Ethernet controller: Broadcom Inc. and subsidiaries BCM57508 NetXtreme-E 10Gb/25Gb/40Gb/50Gb  
/100Gb/200Gb Ethernet (rev 11)
```

```
[root@bb024 ~]# ibstat
CA 'bnxt_re0'
  CA type: Broadcom NetXtreme RoCE HCA
  Number of ports: 1
  Firmware version: 222.0.144.0
  Hardware version: 0x14e4
  Node GUID: 0x86160cffffe6b3c90
  System image GUID: 0x86160cffffe6b3c90
  Port 1:
    State: Active
    Physical state: LinkUp
    Rate: 100
    Base lid: 0
    LMC: 0
    SM lid: 0
    Capability mask: 0x041d0000
    Port GUID: 0x86160cffffe6b3c90
    Link layer: Ethernet
```

NVMe over Fabrics (NVMe-oF) Storage Backend

Solid State Drive (SSD)

Intel Solid State Drive DC P3600 Series PCIe NVMe SSDs have been used in this testing.



Linux NVMe-oF Storage Target

Linux NVMe-oF target software is used to be the storage backend secured by Bloombase StoreSafe Intelligent Storage Firewall.

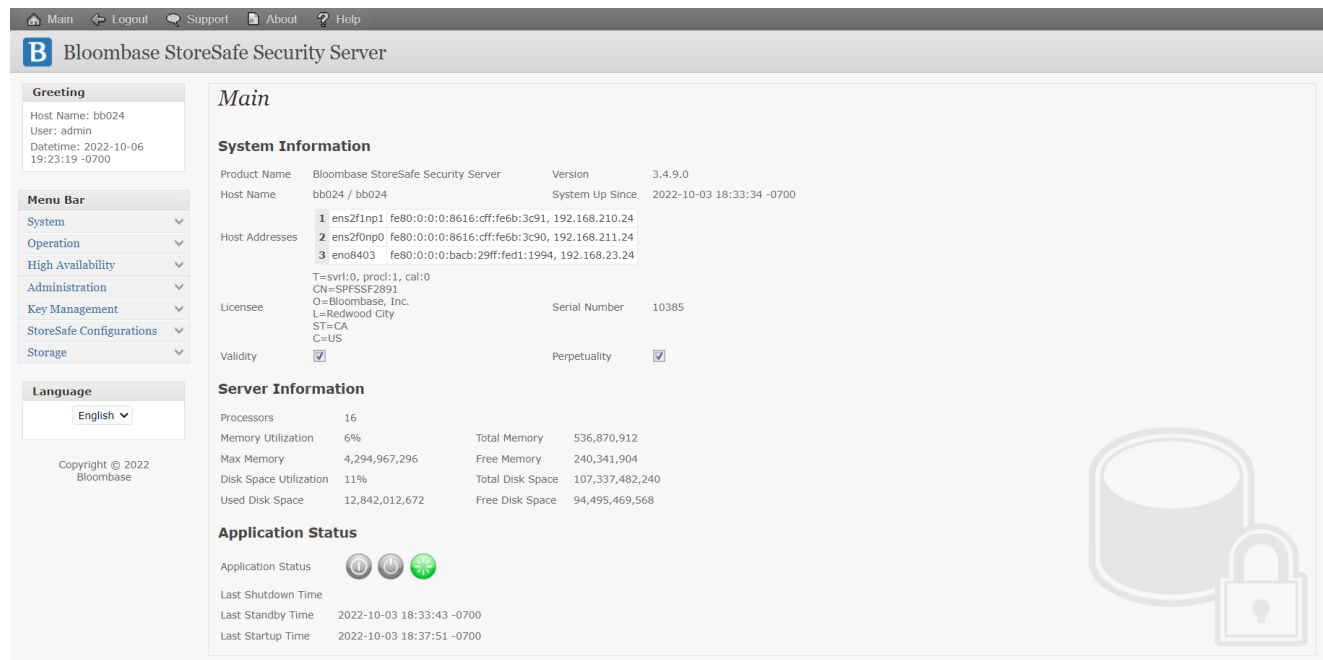
```
[root@bb024 ~]# nvme discover -t rdma -a 192.168.210.32 -s 4420

Discovery Log Number of Records 2, Generation counter 2
=====Discovery Log Entry 0=====
trtype:   rdma
adrfam:   ipv4
subtype:  nvme subsystem
treq:     not required
portid:   1
trsvcid:  4420
subnqn:   nqn.2022-06.io.nvme:node1
traddr:   192.168.210.32
rdma_prtype: not specified
rdma_qptype: connected
rdma_cms:  rdma-cm
rdma_pkey: 0x0000
=====Discovery Log Entry 1=====
trtype:   tcp
adrfam:   ipv4
subtype:  nvme subsystem
treq:     not required
portid:   0
trsvcid:  4420
subnqn:   nqn.2022-06.io.nvme:node1
traddr:   192.168.210.32
sectype:  none
```

Bloombase StoreSafe Intelligent Storage Firewall

Bloombase StoreSafe Intelligent Storage Firewall delivers unified data at-rest encryption security of files, block devices, objects, sequential storages, etc. In this interoperability test, NVMe/RoCE and NVMe/TCP block-based encryption security services are validated against Bloombase StoreSafe Intelligent Storage Firewall with 100GbE connectivity powered by Broadcom NetXtreme P2100G NIC.

Bloombase StoreSafe Intelligent Storage Firewall software appliance is deployed on bare metal Dell PowerEdge T150 Server.



Bloombase StoreSafe Security Server

Greeting
Host Name: bb024
User: admin
Datetime: 2022-10-06 19:23:19 -0700

Menu Bar
System
Operation
High Availability
Administration
Key Management
StoreSafe Configurations
Storage

Language
English

Copyright © 2022 Bloombase

Main


System Information

Product Name	Bloombase StoreSafe Security Server	Version	3.4.9.0
Host Name	bb024 / bb024	System Up Since	2022-10-03 18:33:34 -0700
Host Addresses	<ol style="list-style-type: none"> ens2f1np1 fe80:0:0:0:8616:cff:fe6b:3c91, 192.168.210.24 ens2f0np0 fe80:0:0:0:8616:cff:fe6b:3c90, 192.168.211.24 eno8403 fe80:0:0:0:bacb:29ff:fed1:1994, 192.168.23.24 		
Licensee	T=svrl:0, prod:1, cal:0 CN=SPFSSF2891 O=Bloombase, Inc. L=Redwood City ST=CA C=US	Serial Number	10385
Validity	<input checked="" type="checkbox"/>	Perpetuality	<input checked="" type="checkbox"/>

Server Information

Processors	16	Total Memory	536,870,912
Memory Utilization	6%	Free Memory	240,341,904
Max Memory	4,294,967,296	Total Disk Space	107,337,482,240
Disk Space Utilization	11%	Free Disk Space	94,495,469,568
Used Disk Space	12,842,012,672		

Application Status

Application Status 

Last Shutdown Time
Last Standby Time 2022-10-03 18:33:43 -0700
Last Startup Time 2022-10-03 18:37:51 -0700

Broadcom NetXtreme P2100G NIC and Bloombase StoreSafe Integration

Broadcom NetXtreme P2100G NIC is installed on Dell PowerEdge T150 Server running Bloombase StoreSafe Intelligent Storage Firewall Software Appliance v3.4.9.0.

```
[root@bb024 ~]# lshw -class network -short | grep ens2f0np0
/0/100/1/0      ens2f0np0    network      BCM57508 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet
[root@bb024 ~]# ifconfig ens2f0np0
ens2f0np0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.211.24 netmask 255.255.255.0 broadcast 192.168.211.255
    inet6 fe80::8616:cff:fe6b:3c90 prefixlen 64 scopeid 0x20<link>
    ether 84:16:0c:6b:3c:90 txqueuelen 1000 (Ethernet)
    RX packets 572 bytes 73450 (71.7 KiB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1932 bytes 2376292 (2.2 MiB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

```
[root@bb024 ~]# lspci | grep Broadcom
01:00.0 Ethernet controller: Broadcom Inc. and subsidiaries BCM57508 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet (rev 11)
01:00.1 Ethernet controller: Broadcom Inc. and subsidiaries BCM57508 NetXtreme-E 10Gb/25Gb/40Gb/50Gb/100Gb/200Gb Ethernet (rev 11)
```



```
[root@bb024 ~]# ibstat
CA 'bnxt_re0'
  CA type: Broadcom NetXtreme RoCE HCA
  Number of ports: 1
  Firmware version: 222.0.144.0
  Hardware version: 0x14e4
  Node GUID: 0x86160cffffe6b3c90
  System image GUID: 0x86160cffffe6b3c90
  Port 1:
    State: Active
    Physical state: LinkUp
    Rate: 100
    Base lid: 0
    LMC: 0
    SM lid: 0
    Capability mask: 0x041d0000
    Port GUID: 0x86160cffffe6b3c90
    Link layer: Ethernet
```

Key Generation

Create an encryption key with name key01. Choose the algorithm, key bit length, and signature hash.

Modify Key Wrapper

Key Wrapper

Upload Key Contents

Modify Key Source

CRLDP

OCSP

Permissions

Modify Key Wrapper

Name	<input type="text" value="key01"/>
Key Source	Local
Type	Asymmetric
Active	<input checked="" type="checkbox"/>
Exportable	<input type="checkbox"/>
Algorithm	<div>RSA</div>
Key Bit Length	<div>2048</div>
Signature Hash	<div>SHA256</div>
Key Usage	<div><input type="checkbox"/> Digital Signature</div> <div><input type="checkbox"/> Non Repudiation</div> <div><input type="checkbox"/> Key Encipherment</div> <div><input type="checkbox"/> Data Encipherment</div> <div><input type="checkbox"/> Key Agreement</div> <div><input type="checkbox"/> Key Cert Sign</div> <div><input type="checkbox"/> CRL Sign</div> <div><input type="checkbox"/> Encipher Only</div> <div><input type="checkbox"/> Decipher Only</div>

Extended Key Usage	Add Remove
Owner	admin
Last Update Datetime	

Generate

Select “Generate” to create the encryption key.

Modify Key Wrapper

Key Wrapper

Upload Key Contents

Modify Key Source

CRLDP

OCSP

Permissions

Modify Key Wrapper

Name

key01

Key Source

Local

Type

Asymmetric

Active

☒

Exportable

☐

CA

☐

Subject DN

CN=key01


Serial Number

488764635867322147776757 [677ffbe78f4dd455a8f5]

Issuer DN

CN=key01

Certificate

☒ 

Public Key

☒

Private Key

☒

Effective Datetime

2022-09-10 01:46:00 -0700

Expiry Datetime

2032-09-07 01:46:00 -0700

Key Bit Length

2048

Signature Algorithm

SHA256WITHRSA

Key Usage

Extended Key Usage

Owner

admin

Last Update Datetime

2022-09-10 01:46:48 -0700

The newly created encryption key can be seen after successful generation.

Find Key Wrapper

Name

Type

Active

CA

More Options

Find

Reset

Add

	Name	Type	Key Source Type	Active	Status	CA	Subject DN	Issuer DN	Effective Datetime	Expiry Datetime	Last Update Datetime
1	key01	Asymmetric	Local	<input checked="" type="checkbox"/>	Valid	<input type="checkbox"/>	CN=key01	CN=key01	2022-09-10 01:46:00 -0700	2032-09-07 01:46:00 -0700	2022-09-10 01:46:48 -0700

Bloombase StoreSafe Data-at-Rest Encryption for NVMe/RoCE and NVMe/TCP Configuration

Physical storage with Intel Solid State Drive DC P3600 Series PCIe NVMe SSDs is configured to be secured by Bloombase StoreSafe Intelligent Storage Firewall.

Modify Storage Configuration

Physical Storage Permissions

Physical Storage Configuration

Name	nvme01
Description	
Physical Storage Type	Block
Device ID	1816d452-ac0d-49c2-9de0-d378f0cff5d6
Options	
Device	d9395873-b937-4139-8911-07c347c447c0
Virtual Storage	nqn.2022-06.io.storesafe:nvme01
Owner	admin
Last Update Datetime	2022-10-04 12:16:40 -0700

Virtual storage with “NVMe” mode is created to secure the just configured physical storage.

Modify Virtual Storage

Virtual Storage Protection Access Control Permissions

Modify Virtual Storage

Name

Status ☒

Description

Active ☒

Mode NVMe

Model

Serial Number

Owner admin

Last Update Datetime 2022-10-05 10:03:21 -0700

Physical Storage

		Storage	Description	Device
1	<input type="checkbox"/>	nvme01		d9395873-b937-4139-8911-07c347c447c0

Select “Privacy” for protection type and select the encryption key. Choose the cipher algorithm and bit length.

Modify Virtual Storage Handler

Virtual Storage Protection Access Control Permissions

Virtual Storage Protection

Protection Type

Encryption Keys

		Key Name	Last Update Datetime
1	<input type="checkbox"/>	key01	2022-09-10 01:58:41 -0700

[Remove](#)

Cryptographic Cipher

Cipher Algorithm

Bit Length

Add clients’ NVMe Qualified Name (NQN) that can access Bloombase StoreSafe virtual storage.

Modify Virtual Storage Access Control

Virtual Storage
Protection
Access Control
Permissions

Initiators

		Initiator	Alias	Warning	Last Update Datetime
1	<input type="checkbox"/>	nqn.2014-08.org.nvmexpress:uuid:cf2eae42-6537-4891-85c2-77bbff4598b8			2022-06-03 14:50:03 -0700
2	<input type="checkbox"/>	nqn.2014-08.org.nvmexpress:uuid:98c22f42-0694-af6d-1b5b-6d7b4ea9944d			2022-07-13 12:20:18 -0700

Start Bloombase StoreSafe virtual storage.

Virtual Storage Status

Virtual Storage

Name nqn.2022-06.io.storesafe:nvme01
Status ☒
Active ☒
Type NVMe

Physical Storage

Name nvme01
Type Unknown

Active Share Status

Share Name nqn.2022-06.io.storesafe:nvme01
Storage Type Unknown
Storage Path Target : nqn.2022-06.io.storesafe:nvme01
LUN 1:[_SS_nvme33n1__];
Sessions 2 🔑

Refresh
Stop
Start
Close

Storage Client

Client host running Red Hat Enterprise Linux (RHEL) 8.6 is used to access Bloombase StoreSafe Intelligent Storage Firewall virtual storage.

```
[root@bb027 ~]# uname -a
Linux bb027.ca.bloombase.com 4.18.0-372.9.1.el8.x86_64 #1 SMP Tue May 10 14:48:47 UTC 2022 x86_64 x86_64 x86_64 GNU/Linux
```

```
[root@bb027 ~]# nvme version
nvme version 1.16
```

Test Cases

Functional Tests for Data-at-Rest Encryption over NVMe/RoCE

Client that has appropriate access can discover Bloomberg StoreSafe Intelligent Storage Firewall virtual storage over NVMe/RoCE protocol.

```
[root@bb027 ~]# nvme discover -t rdma -a 192.168.211.24 -s 4420 -q nqn.2014-08.org.nvmexpress:uuid:c  
f2eae42-6537-4891-85c2-77bbff4598b8
```

```
trtype: rdma  
adrfam: ipv4  
subtype: nvme subsystem  
treq: not required  
portid: 0  
trsvcid: 4420  
subnqn: nqn.2022-06.io.storesafe:nvme01  
traddr: 192.168.211.24  
rdma_prtype: not specified  
rdma_qptype: connected  
rdma_cms: rdma-cm  
rdma_pkey: 0x0000
```

Connect client to Bloomberg StoreSafe Intelligent Storage Firewall virtual storage.

```
[root@bb027 ~]# nvme connect -t rdma -a 192.168.211.24 -s 4420 -q nqn.2014-08.org.nvmexpress:uuid:cf2eae42-6537-4891-85c2-77bbff4598b8 -n nqn.2022-06.io.storesafe:nvme01
```

Ensure that Bloomberg StoreSafe Intelligent Storage Firewall virtual storage is attached to the client after successful connection.

```
[root@bb027 ~]# lsblk
NAME        MAJ:MIN RM  SIZE RO TYPE MOUNTPOINT
sda          8:0    0  1.8T  0 disk
├─sda1       8:1    0   600M  0 part /boot/efi
├─sda2       8:2    0    1G    0 part /boot
├─sda3       8:3    0  1.8T  0 part
├─rl-root    253:0   0   70G   0 lvm  /
├─rl-swap    253:1   0  15.7G  0 lvm  [SWAP]
└─rl-home    253:2   0  1.8T   0 lvm  /home
nvme0n1      259:0   0  1.1T  0 disk
```

Format and mount Bloomberg Storesafe Intelligent Storage Firewall virtual storage.

```
[root@bb027 ~]# mount /dev/nvme0n1 /nvme01
[root@bb027 ~]# mount | grep nvme01
/dev/nvme0n1 on /nvme01 type xfs (rw,relatime,seclabel,attr2,inode64,logbufs=8,logbsize=32k,noquota)
[root@bb027 ~]# cd /nvme01/
```

Read Test

Sample plaintext files have been pre-added into Bloomberg StoreSafe Intelligent Storage Firewall virtual storage.

```
[root@bb027 nvme01]# ls -l
total 261336
-rw-r--r--. 1 root root      3285 Aug 13  2021 0.seq
-rw-r--r--. 1 root root      3201 Aug 13  2021 100.seq
-rw-r--r--. 1 root root      3066 Aug 13  2021 101.seq
-rw-r--r--. 1 root root      3191 Aug 13  2021 102.seq
-rw-r--r--. 1 root root      3362 Aug 13  2021 103.seq
-rw-r--r--. 1 root root      3275 Aug 13  2021 104.seq
-rw-r--r--. 1 root root      3192 Aug 13  2021 105.seq
-rw-r--r--. 1 root root      3204 Aug 13  2021 106.seq
-rw-r--r--. 1 root root      3200 Aug 13  2021 107.seq
-rw-r--r--. 1 root root      3184 Aug 13  2021 108.seq
-rw-r--r--. 1 root root      3155 Aug 13  2021 109.seq
-rw-r--r--. 1 root root      2993 Aug 13  2021 10.seq
-rw-r--r--. 1 root root      3044 Aug 13  2021 110.seq
-rw-r--r--. 1 root root      3287 Aug 13  2021 111.seq
```

Trusted client is able to access and read plaintext files.

```

//
LOCUS      AQ721632                506 bp    DNA        linear    GSS 09-MAY-2010
DEFINITION HS_5563_B1_B06 T7A RPCI-11 Human Male BAC Library Homo sapiens
            genomic clone Plate=1139 Col=11 Row=D, genomic survey sequence.
ACCESSION  AQ721632
VERSION    AQ721632.1
DBLINK     BioSample: SAMN00183116
KEYWORDS   GSS.
SOURCE     Homo sapiens (human)
  ORGANISM Homo sapiens
            Eukaryota; Metazoa; Chordata; Craniata; Vertebrata; Euteleostomi;
            Mammalia; Eutheria; Euarchontoglires; Primates; Haplorrhini;
            Catarrhini; Hominidae; Homo.
REFERENCE  1 (bases 1 to 506)
  AUTHORS  Mahairas,G.G., Wallace,J.C., Smith,K., Swartzell,S., Holzman,T.,
            Keller,A., Shaker,R., Furlong,J., Young,J., Zhao,S., Adams,M.D. and
            Hood,L.
  TITLE    Sequence-tagged connectors: A sequence approach to mapping and
            scanning the human genome
  JOURNAL  Proc. Natl. Acad. Sci. U.S.A. 96 (17), 9739-9744 (1999)
  PUBMED   10449764
COMMENT    Contact: Mahairas GG, Wallace JC, Hood L
            High Throughput Sequencing Center
            University of Washington
            401 Queen Anne Avenue North, Seattle, WA 98109, USA
            Tel: (206) 616-3618
            Fax: (206) 616-3887
            Email: jwallace@u.washington.edu
"100.seq" 60L, 3201C

```

Any file/data stored via Bloombase StoreSafe Intelligent Storage Firewall virtual storage is seamlessly encrypted at the storage with zero operational impact to end users, system administrators and software applications.

```
[root@bb024 ~]# hexdump -C /dev/nvme0n1
```

```

00391940  61 cd fa af e1 12 60 48  a0 b9 07 ee 96 c4 58 82  |a....`H.....X.|
00391950  b4 2a 9e 8c 44 ee 9e 93  22 d4 30 88 2e 1f 56 1a  |.*..D..."0...V.|
00391960  4e 21 56 87 78 a6 3c 5c  1b dd 93 28 d3 a3 c7 fe  |N!V.x.<\...(...|
00391970  02 c7 3f a3 51 2d 2b 7c  2b 32 aa 5a 21 55 06 53  |...?.Q-+|+2.Z!U.S|
00391980  b0 bf dd 43 32 a2 30 49  fc ce c7 e2 8a 51 fe 9d  |...C2.0I.....Q..|
00391990  1c af 55 9e 50 bc 4c a9  39 eb b0 96 bd d6 60 df  |..U.P.L.9.....`.|
003919a0  ed 48 25 bf ae 11 93 90  96 bc 46 5f 6d 18 25 5c  |.H%.....F m.%\|
003919b0  e9 ea 62 b0 dc a2 45 75  5c ca 0b 22 df 78 fd b3  |..b...Eu\..."x..|
003919c0  05 19 15 26 0f 1c 70 f4  03 09 33 6d eb 67 e2 7e  |...&...p...3m.g.~|
003919d0  8f 38 fe 6f 5f 99 b3 d3  4f bb 21 71 9e 6b 67 8a  |.8.o_...O.!q.kg.|
003919e0  bb c9 d0 8f c2 10 99 13  fa a3 8d 65 34 36 d1 44  |.....e46.D|
003919f0  96 f0 3f 76 d4 a0 d4 6b  7b 77 c4 1f d8 db 2d db  |...?v...k{w....-|
00391a00  ab 5f 41 9a d4 bc 00 89  6d 3b bb 1f 10 e0 c4 cb  |. _A.....m;.....|
00391a10  4d e0 a6 28 ab 3e e6 5a  fa ad fe 20 9a 9d ca cd  |M..(>.Z... ....|
00391a20  e4 b9 22 fa 61 4a 6e 7b  c1 82 4c ad fe 3a 72 d1  |..".aJn{..L.:r.|
00391a30  16 81 a7 32 f6 8c ab 33  f4 ed a0 5d 78 75 d7 9b  |...2...3...]xu..|
00391a40  fe f8 7a dc 39 9f 87 75  c4 cd f7 3c bd c2 43 7e  |...z.9..u...<..C~|
00391a50  d8 a2 47 6f 98 ea da ed  d5 a2 40 c7 44 94 03 df  |..Go.....@.D...|

```

```

[root@bb024 ~]# hexdump -C /dev/nvme0n1 | grep SAMN00183116
[root@bb024 ~]#

```

Write Test

Create a new file to be secured by Bloombase StoreSafe Intelligent Storage Firewall.


```
[root@bb027 nvme01]# vi password.txt
```

```
My IRS password: iloveyou
My Citibank password: qwertyuiop
```

Trusted client is able to access and write files into Bloombase StoreSafe Intelligent Storage Firewall.

```
[root@bb027 nvme01]# ls -l | grep password.txt
-rw-r--r--. 1 root root      60 Oct  5 08:03 password.txt
```

```
[root@bb027 nvme01]# cat password.txt
My IRS password: iloveyou
My Citibank password: qwertyuiop
```

Any file/data stored via Bloombase StoreSafe Intelligent Storage Firewall virtual storage is seamlessly encrypted at the storage with zero operational impact to end users, system administrators and software applications.

```
[root@bb024 ~]# hexdump -C /dev/nvme0n1
```

```
00391940  61 cd fa af e1 12 60 48  a0 b9 07 ee 96 c4 58 82  |a.....`H.....X.|
00391950  b4 2a 9e 8c 44 ee 9e 93  22 d4 30 88 2e 1f 56 1a  |*..D..."0...V.|
00391960  4e 21 56 87 78 a6 3c 5c  1b dd 93 28 d3 a3 c7 fe  |N!V.x.<\...(...|
00391970  02 c7 3f a3 51 2d 2b 7c  2b 32 aa 5a 21 55 06 53  |..?.Q-+|+2.Z!U.S|
00391980  b0 bf dd 43 32 a2 30 49  fc ce c7 e2 8a 51 fe 9d  |...C2.0I.....Q..|
00391990  1c af 55 9e 50 bc 4c a9  39 eb b0 96 bd d6 60 df  |..U.P.L.9.....`.|
003919a0  ed 48 25 bf ae 11 93 90  96 bc 46 5f 6d 18 25 5c  |.H%.....F_m.%\|
003919b0  e9 ea 62 b0 dc a2 45 75  5c ca 0b 22 df 78 fd b3  |..b...Eu\".x..|
003919c0  05 19 15 26 0f 1c 70 f4  03 09 33 6d eb 67 e2 7e  |...&..p...3m.g.~|
003919d0  8f 38 fe 6f 5f 99 b3 d3  4f bb 21 71 9e 6b 67 8a  |.8.o_...O.!q.kg.|
003919e0  bb c9 d0 8f c2 10 99 13  fa a3 8d 65 34 36 d1 44  |.....e46.D|
003919f0  96 f0 3f 76 d4 a0 d4 6b  7b 77 c4 1f d8 db 2d db  |...?v...k{w....-|
00391a00  ab 5f 41 9a d4 bc 00 89  6d 3b bb 1f 10 e0 c4 cb  |. _A.....m;.....|
00391a10  4d e0 a6 28 ab 3e e6 5a  fa ad fe 20 9a 9d ca cd  |M..(>.Z... ..|
00391a20  e4 b9 22 fa 61 4a 6e 7b  c1 82 4c ad fe 3a 72 d1  |..".aJn{...L.:r.|
00391a30  16 81 a7 32 f6 8c ab 33  f4 ed a0 5d 78 75 d7 9b  |...2...3...]xu..|
00391a40  fe f8 7a dc 39 9f 87 75  c4 cd f7 3c bd c2 43 7e  |..z.9..u...<..C~|
00391a50  d8 a2 47 6f 98 ea da ed  d5 a2 40 c7 44 94 03 df  |..Go.....@.D...|
```

```
[root@bb024 ~]# hexdump -C /dev/nvme0n1 | grep password
[root@bb024 ~]#
```

Functional Tests for Data-at-Rest Encryption over NVMe/TCP

Client that has appropriate access can discover Bloombase StoreSafe Intelligent Storage Firewall virtual storage over NVMe/TCP protocol.

```
[root@bb027 ~]# nvme discover -t tcp -a 192.168.211.24 -s 4420 -q nqn.2014-08.org.nvmexpress:uuid:cf2eae42-6537-4891-85c2-77bbff4598b8
```

```
trtype: tcp
adrfam: ipv4
subtype: nvme subsystem
treq: not required
portid: 1
trsvcid: 4420
subnqn: nqn.2022-06.io.storesafe:nvme01
traddr: 192.168.211.24
sectype: none
```

Connect client to Bloombase StoreSafe Intelligent Storage Firewall virtual storage.

```
[root@bb027 ~]# nvme connect -t tcp -a 192.168.211.24 -s 4420 -q nqn.2014-08.org.nvmexpress:uuid:cf2eae42-6537-4891-85c2-77bbff4598b8 -n nqn.2022-06.io.storesafe:nvme01
```

Ensure that Bloombase StoreSafe Intelligent Storage Firewall virtual storage is attached to the client after successful connection.

```
[root@bb027 ~]# lsblk
NAME        MAJ:MIN RM  SIZE RO TYPE MOUNTPOINT
sda          8:0    0  1.8T  0 disk
├─sda1       8:1    0   600M  0 part /boot/efi
├─sda2       8:2    0    1G    0 part /boot
├─sda3       8:3    0  1.8T  0 part
│   └─rl-root 253:0    0   70G    0 lvm  /
│       └─rl-swap 253:1    0  15.7G    0 lvm  [SWAP]
│           └─rl-home 253:2    0  1.8T    0 lvm  /home
nvme0n1     259:0    0  1.1T  0 disk
```

Format and mount Bloombase Storesafe Intelligent Storage Firewall virtual storage.

```
[root@bb027 ~]# mount /dev/nvme0n1 /nvme01
[root@bb027 ~]# mount | grep nvme01
/dev/nvme0n1 on /nvme01 type xfs (rw,relatime,seclabel,attr2,inode64,logbufs=8,logbsize=32k,noquota)
[root@bb027 ~]# cd /nvme01/
```

Read Test

Sample plaintext files have been pre-added into Bloombase StoreSafe Intelligent Storage Firewall virtual storage.

```
[root@bb027 nvme01]# ls -l
total 261336
-rw-r--r--. 1 root root      3285 Aug 13  2021 0.seq
-rw-r--r--. 1 root root      3201 Aug 13  2021 100.seq
-rw-r--r--. 1 root root      3066 Aug 13  2021 101.seq
-rw-r--r--. 1 root root      3191 Aug 13  2021 102.seq
-rw-r--r--. 1 root root      3362 Aug 13  2021 103.seq
-rw-r--r--. 1 root root      3275 Aug 13  2021 104.seq
-rw-r--r--. 1 root root      3192 Aug 13  2021 105.seq
-rw-r--r--. 1 root root      3204 Aug 13  2021 106.seq
-rw-r--r--. 1 root root      3200 Aug 13  2021 107.seq
-rw-r--r--. 1 root root      3184 Aug 13  2021 108.seq
-rw-r--r--. 1 root root      3155 Aug 13  2021 109.seq
-rw-r--r--. 1 root root      2993 Aug 13  2021 10.seq
-rw-r--r--. 1 root root      3044 Aug 13  2021 110.seq
-rw-r--r--. 1 root root      3287 Aug 13  2021 111.seq
```

Trusted client is able to access and read plaintext files.

```

/
LOCUS      AQ721632                506 bp    DNA        linear    GSS 09-MAY-2010
DEFINITION HS_5563_B1_B06_T7A RPCI-11 Human Male BAC Library Homo sapiens
            genomic clone Plate=1139 Col=11 Row=D, genomic survey sequence.
ACCESSION  AQ721632
VERSION    AQ721632.1
DBLINK     BioSample: SAMN00183116
KEYWORDS   GSS.
SOURCE     Homo sapiens (human)
  ORGANISM Homo sapiens
            Eukaryota; Metazoa; Chordata; Craniata; Vertebrata; Euteleostomi;
            Mammalia; Eutheria; Euarchontoglires; Primates; Haplorrhini;
            Catarrhini; Hominidae; Homo.
REFERENCE  1 (bases 1 to 506)
  AUTHORS  Mahairas,G.G., Wallace,J.C., Smith,K., Swartzell,S., Holzman,T.,
            Keller,A., Shaker,R., Furlong,J., Young,J., Zhao,S., Adams,M.D. and
            Hood,L.
  TITLE    Sequence-tagged connectors: A sequence approach to mapping and
            scanning the human genome
  JOURNAL  Proc. Natl. Acad. Sci. U.S.A. 96 (17), 9739-9744 (1999)
  PUBMED   10449764
COMMENT    Contact: Mahairas GG, Wallace JC, Hood L
            High Throughput Sequencing Center
            University of Washington
            401 Queen Anne Avenue North, Seattle, WA 98109, USA
            Tel: (206) 616-3618
            Fax: (206) 616-3887
            Email: jwallace@u.washington.edu
"100.seq" 60L, 3201C
  
```

Any file/data stored via Bloombase StoreSafe Intelligent Storage Firewall virtual storage is seamlessly encrypted at the storage with zero operational impact to end users, system administrators and software applications.

```
[root@bb024 ~]# hexdump -C /dev/nvme0n1
```

```

00391940  61 cd fa af e1 12 60 48  a0 b9 07 ee 96 c4 58 82  |a.....`H.....X.|
00391950  b4 2a 9e 8c 44 ee 9e 93  22 d4 30 88 2e 1f 56 1a  |.*..D..."0...V.|
00391960  4e 21 56 87 78 a6 3c 5c  1b dd 93 28 d3 a3 c7 fe  |N!V.x.<\...(....|
00391970  02 c7 3f a3 51 2d 2b 7c  2b 32 aa 5a 21 55 06 53  |...?Q~+|+2.Z!U.S|
00391980  b0 bf dd 43 32 a2 30 49  fc ce c7 e2 8a 51 fe 9d  |...C2.0I.....Q..|
00391990  1c af 55 9e 50 bc 4c a9  39 eb b0 96 bd d6 60 df  |...U.P.L.9.....`.|
003919a0  ed 48 25 bf ae 11 93 90  96 bc 46 5f 6d 18 25 5c  |.H%.....F_m.%\|
003919b0  e9 ea 62 b0 dc a2 45 75  5c ca 0b 22 df 78 fd b3  |...b...Eu\..."x..|
003919c0  05 19 15 26 0f 1c 70 f4  03 09 33 6d eb 67 e2 7e  |...&..p...3m.g.~|
003919d0  8f 38 fe 6f 5f 99 b3 d3  4f bb 21 71 9e 6b 67 8a  |.8.o_...O.!q.kg.|
003919e0  bb c9 d0 8f c2 10 99 13  fa a3 8d 65 34 36 d1 44  |.....e46.D|
003919f0  96 f0 3f 76 d4 a0 d4 6b  7b 77 c4 1f d8 db 2d db  |...?v...k{w....-.|
00391a00  ab 5f 41 9a d4 bc 00 89  6d 3b bb 1f 10 e0 c4 cb  |. _A.....m;.....|
00391a10  4d e0 a6 28 ab 3e e6 5a  fa ad fe 20 9a 9d ca cd  |M..(>.Z... ....|
00391a20  e4 b9 22 fa 61 4a 6e 7b  c1 82 4c ad fe 3a 72 d1  |..."aJn{...L...:r.|
00391a30  16 81 a7 32 f6 8c ab 33  f4 ed a0 5d 78 75 d7 9b  |...2...3...]xu...|
00391a40  fe f8 7a dc 39 9f 87 75  c4 cd f7 3c bd c2 43 7e  |...z.9.u...<..C~|
00391a50  d8 a2 47 6f 98 ea da ed  d5 a2 40 c7 44 94 03 df  |...Go.....@.D...|
  
```

```

[root@bb024 ~]# hexdump -C /dev/nvme0n1 | grep SAMN00183116
[root@bb024 ~]#
  
```

Write Test

Create a new file to be secured by Bloombase StoreSafe Intelligent Storage Firewall.

```
[root@bb027 nvme01]# vi password.txt
```

```
My IRS password: iloveyou
My Citibank password: qwertyuiop
```

Trusted client is able to access and write files into Bloombase StoreSafe Intelligent Storage Firewall.

```
[root@bb027 nvme01]# ls -l | grep password.txt
-rw-r--r--. 1 root root      60 Oct  5 08:03 password.txt
```

```
[root@bb027 nvme01]# cat password.txt
My IRS password: iloveyou
My Citibank password: qwertyuiop
```

Any file/data stored via Bloombase StoreSafe Intelligent Storage Firewall virtual storage is seamlessly encrypted at the storage with zero operational impact to end users, system administrators and software applications.

```
[root@bb024 ~]# hexdump -C /dev/nvme0n1
```

```
00391940  61 cd fa af e1 12 60 48 a0 b9 07 ee 96 c4 58 82 |a.....`H.....X.|
00391950  b4 2a 9e 8c 44 ee 9e 93 22 d4 30 88 2e 1f 56 1a |.*..D..."0...V.|
00391960  4e 21 56 87 78 a6 3c 5c 1b dd 93 28 d3 a3 c7 fe |N!V.x.<\...(...|
00391970  02 c7 3f a3 51 2d 2b 7c 2b 32 aa 5a 21 55 06 53 |...?.Q-+|+2.Z!U.S|
00391980  b0 bf dd 43 32 a2 30 49 fc ce c7 e2 8a 51 fe 9d |...C2.0I.....Q..|
00391990  1c af 55 9e 50 bc 4c a9 39 eb b0 96 bd d6 60 df |..U.P.L.9.....`.|
003919a0  ed 48 25 bf ae 11 93 90 96 bc 46 5f 6d 18 25 5c |.H%.....F_m.%\|
003919b0  e9 ea 62 b0 dc a2 45 75 5c ca 0b 22 df 78 fd b3 |..b...Eu\..."x..|
003919c0  05 19 15 26 0f 1c 70 f4 03 09 33 6d eb 67 e2 7e |...&..p...3m.g.~|
003919d0  8f 38 fe 6f 5f 99 b3 d3 4f bb 21 71 9e 6b 67 8a |.8.o....O.!q.kg.|
003919e0  bb c9 d0 8f c2 10 99 13 fa a3 8d 65 34 36 d1 44 |....e46.D|
003919f0  96 f0 3f 76 d4 a0 d4 6b 7b 77 c4 1f d8 db 2d db |...?v...k{w....-|
00391a00  ab 5f 41 9a d4 bc 00 89 6d 3b bb 1f 10 e0 c4 cb |._A.....m;.....|
00391a10  4d e0 a6 28 ab 3e e6 5a fa ad fe 20 9a 9d ca cd |M..(>.Z... ..|
00391a20  e4 b9 22 fa 61 4a 6e 7b c1 82 4c ad fe 3a 72 d1 |..".aJn{..L.:r.|
00391a30  16 81 a7 32 f6 8c ab 33 f4 ed a0 5d 78 75 d7 9b |...2...3...]xu..|
00391a40  fe f8 7a dc 39 9f 87 75 c4 cd f7 3c bd c2 43 7e |...z.9..u...<..C~|
00391a50  d8 a2 47 6f 98 ea da ed d5 a2 40 c7 44 94 03 df |..Go.....@.D...|
```

```
[root@bb024 ~]# hexdump -C /dev/nvme0n1 | grep password
[root@bb024 ~]#
```

Throughput Tests for Data-at-Rest Encryption over NVMe/RoCE

Bloombase StoreSafe Intelligent Storage Firewall equipped with Broadcom NetXtreme P2100G NIC provides encryption over NVMe/RoCE with high throughput.

FIO benchmarking tool is used to generate high number of I/Os and bytes to accurately test Bloombase StoreSafe Intelligent Storage Firewall virtual storage performance.

Read Test

Read throughput test is performed using fio with below test parameters:

```
[root@bb027 ~]# cat readthroughput.fio
[global]
bs=1M
iodepth=1
direct=1
ioengine=libaio
group_reporting
time_based
runtime=180
numjobs=1
name=readthroughput
rw=randread

[job1]
filename=/dev/nvme0n1
```

```
Run status group 0 (all jobs):
  READ: bw=858MiB/s (900MB/s), 858MiB/s-858MiB/s (900MB/s-900MB/s), io=151GiB (162GB), run=180002-180002msec
```

Write Test

Write throughput test is performed using fio with below test parameters:

```
[root@bb027 ~]# cat writethroughput.fio
[global]
bs=1M
iodepth=1
direct=1
ioengine=libaio
group_reporting
time_based
runtime=180
numjobs=1
name=writethroughput
rw=randwrite

[job1]
filename=/dev/nvme0n1
```

```
Run status group 0 (all jobs):  
  WRITE: bw=999MiB/s (1047MB/s), 999MiB/s-999MiB/s (1047MB/s-1047MB/s), io=176GiB (188GB), run=180001-180001msec
```

Throughput Tests for Data-at-Rest Encryption over NVMe/TCP

Bloombase StoreSafe Intelligent Storage Firewall equipped with Broadcom NetXtreme P2100G NIC provides encryption over NVMe/TCP with high throughput.

Read Test

Read throughput test is performed using fio with below test parameters:

```
[root@bb027 ~]# cat readthroughput.fio  
[global]  
bs=1M  
iodepth=1  
direct=1  
ioengine=libaio  
group_reporting  
time_based  
runtime=180  
numjobs=1  
name=readthroughput  
rw=randread  
  
[job1]  
filename=/dev/nvme0n1
```

```
Run status group 0 (all jobs):  
  READ: bw=730MiB/s (765MB/s), 730MiB/s-730MiB/s (765MB/s-765MB/s), io=128GiB (138GB), run=180001-180001msec
```

Write Test

Write throughput test is performed using fio with below test parameters:

```
[root@bb027 ~]# cat writethroughput.fio  
[global]  
bs=1M  
iodepth=1  
direct=1  
ioengine=libaio  
group_reporting  
time_based  
runtime=180  
numjobs=1  
name=writethroughput  
rw=randwrite  
  
[job1]  
filename=/dev/nvme0n1
```

```
Run status group 0 (all jobs):
  WRITE: bw=831MiB/s (872MB/s), 831MiB/s-831MiB/s (872MB/s-872MB/s), io=146GiB (157GB), run=180001-180001msec
```

Latency Tests for Data-at-Rest Encryption over NVMe/RoCE

Bloombase StoreSafe Intelligent Storage Firewall equipped with Broadcom NetXtreme P2100G NIC provides encryption over NVMe/RoCE with low latency.

Read Test

Read latency test is performed using fio with below test parameters:

```
[root@bb027 ~]# cat readlatency.fio
[global]
bs=4K
iodepth=1
direct=1
ioengine=libaio
group_reporting
time_based
runtime=180
numjobs=1
name=readlatency
rw=randread

[job1]
filename=/dev/nvme0n1
```

```
slat (nsec): min=2636, max=40466, avg=4604.39, stdev=2401.30
clat (usec): min=34, max=2981, avg=74.08, stdev=21.90
  lat (usec): min=51, max=2983, avg=78.82, stdev=22.08
clat percentiles (usec):
| 1.00th=[ 58], 5.00th=[ 58], 10.00th=[ 59], 20.00th=[ 59],
| 30.00th=[ 60], 40.00th=[ 63], 50.00th=[ 64], 60.00th=[ 64],
| 70.00th=[ 75], 80.00th=[ 99], 90.00th=[ 113], 95.00th=[ 120],
| 99.00th=[ 128], 99.50th=[ 133], 99.90th=[ 137], 99.95th=[ 139],
| 99.99th=[ 145]
```

Write Test

Write latency test is performed using fio with below test parameters:

```
[root@bb027 ~]# cat writelateny.fio
[global]
bs=4K
iodepth=1
direct=1
ioengine=libaio
group_reporting
time_based
runtime=180
numjobs=1
name=writelateny
rw=randwrite

[job1]
filename=/dev/nvme0n1
```

```
slat (nsec): min=2451, max=34039, avg=2700.48, stdev=494.91
clat (usec): min=7, max=7761, avg=31.47, stdev=13.85
lat (usec): min=27, max=7763, avg=34.26, stdev=13.86
clat percentiles (nsec):
| 1.00th=[30592], 5.00th=[30848], 10.00th=[30848], 20.00th=[30848],
| 30.00th=[31104], 40.00th=[31104], 50.00th=[31360], 60.00th=[31360],
| 70.00th=[31616], 80.00th=[31872], 90.00th=[32128], 95.00th=[32384],
| 99.00th=[36096], 99.50th=[38144], 99.90th=[44800], 99.95th=[46848],
| 99.99th=[59136]
```

Latency Tests for Data-at-Rest Encryption over NVMe/TCP

Bloombase StoreSafe Intelligent Storage Firewall equipped with Broadcom NetXtreme P2100G NIC provides encryption over NVMe/TCP with low latency.

Read Test

Read latency test is performed using fio with below test parameters:

```
[root@bb027 ~]# cat readlatency.fio
[global]
bs=4K
iodepth=1
direct=1
ioengine=libaio
group_reporting
time_based
runtime=180
numjobs=1
name=readlatency
rw=randread

[job1]
filename=/dev/nvme0n1
```

```
slat (nsec): min=3738, max=55760, avg=5486.05, stdev=2674.44
clat (usec): min=35, max=3126, avg=94.17, stdev=21.73
lat (usec): min=69, max=3131, avg=99.84, stdev=22.07
clat percentiles (usec):
| 1.00th=[ 73], 5.00th=[ 75], 10.00th=[ 78], 20.00th=[ 79],
| 30.00th=[ 80], 40.00th=[ 83], 50.00th=[ 84], 60.00th=[ 85],
| 70.00th=[ 100], 80.00th=[ 118], 90.00th=[ 130], 95.00th=[ 139],
| 99.00th=[ 151], 99.50th=[ 157], 99.90th=[ 165], 99.95th=[ 169],
| 99.99th=[ 174]
```


Write Test

Write latency test is performed using fio with below test parameters:

```
[root@bb027 ~]# cat writelateness.fio
[global]
bs=4K
iodepth=1
direct=1
ioengine=libaio
group_reporting
time_based
runtime=180
numjobs=1
name=writelateness
rw=randwrite

[job1]
filename=/dev/nvme0n1
```

```
slat (nsec): min=3637, max=61819, avg=4495.09, stdev=1425.45
clat (usec): min=24, max=7568, avg=44.79, stdev=13.60
lat (usec): min=39, max=7572, avg=49.44, stdev=13.52
clat percentiles (nsec):
| 1.00th=[38144], 5.00th=[38656], 10.00th=[39168], 20.00th=[44800],
| 30.00th=[44800], 40.00th=[44800], 50.00th=[45312], 60.00th=[45824],
| 70.00th=[45824], 80.00th=[45824], 90.00th=[46848], 95.00th=[47360],
| 99.00th=[55552], 99.50th=[57600], 99.90th=[60160], 99.95th=[61696],
| 99.99th=[72192]
```

Throughput and Latency Comparisons of Bloombase StoreSafe Data-at-Rest Encryption using Broadcom NetXtreme P2100G vs Marvell FastLinQ QL45611HLCU

The Broadcom NetXtreme P2100G NICs previously installed at the Bloombase StoreSafe Intelligent Storage Firewall hardware appliance and the storage client are swapped out by Marvell FastLinQ QL45611HLCU with throughput and latency tests redone.

For details of tests on Bloombase StoreSafe Intelligent Storage Firewall with Marvell FastLinQ QL45611HLCU, please refer to Appendix A.

The test results are entered into the grids below.

Throughput Test Results

Test	Broadcom NetXtreme P2100G	Marvell FastLinQ QL45611HLCU
NVMe/RoCE Read	986 MB/s	939 MB/s (-4.77%)
NVMe/RoCE Write	1047 MB/s	1029 MB/s (-1.72%)

NVMe/TCP Read	765 MB/s	738 MB/s (-3.52%)
NVMe/TCP Write	872 MB/s	851 MB/s (-2.41%)

Latency Test Results

Test	Broadcom NetXtreme P2100G	Marvell FastLinQ QL45611HLCU
NVMe/RoCE Read	78.82 us	84.19 us (+6.81%)
NVMe/RoCE Write	34.26 us	44.62 us (+30.24%)
NVMe/TCP Read	99.84 us	141.50 us (+41.73%)
NVMe/TCP Write	49.44 us	58.63 us (+18.59%)

Conclusion

In this integration guide, we have shown how to set up Bloombase StoreSafe Intelligent Storage Firewall with Broadcom NetXtreme P2100G NIC to deliver on-the-fly encryption over NVMe-oF storage protocols. The end result is a high-bandwidth, low-latency storage encryption solution that locks down sensitive crown-jewel data on all-flash storage (AFS) using post-quantum cryptography (PQC) cipher algorithms. The solution helps organizations mitigate information exfiltration threats for mission-critical systems and data services.

As a summary,

- Broadcom NetXtreme P2100G NIC

has been integrated with Bloombase StoreSafe Intelligent Storage Firewall to deliver encryption security of NVMe/RoCE and NVMe/TCP storage services for Red Hat Enterprise Linux (RHEL) 8.6.

Bloombase Product	Client Host and Storage Backend	Network
Bloombase StoreSafe Intelligent Storage Firewall	<ul style="list-style-type: none">• Red Hat Enterprise Linux (RHEL) 8.6• NVMe/RoCE storage services on Red Hat Enterprise Linux (RHEL) 8.6 with Intel Solid State Drive DC P3600 Series PCIe	<ul style="list-style-type: none">• Broadcom NetXtreme P2100G NIC• Celestica Seastone DXo10 32-port 100GbE ONIE Switch

NVMe SSD

- NVMe/TCP storage services on Red Hat Enterprise Linux (RHEL) 8.6 with Intel Solid State Drive DC P3600 Series PCIe NVMe SSD

- NVIDIA/Mellanox 100GbE QSFP28 DAC Cables



Disclaimer

The integration procedures described in this paper were conducted in the Bloombase InteropLab. Bloombase has not tested this configuration with all the combinations of hardware and software options available. There may be significant difference in your configuration that will change the procedures necessary to accomplish the objectives outlined in this paper. If you find that any of these procedures do not work in your environment, please contact us immediately.

Acknowledgement

Bloombase InteropLab would like to thank Broadcom team for supporting the integration of Bloombase StoreSafe with Broadcom NetXtreme P2100G NIC.

Reference

1. Bloombase StoreSafe Technical Specifications, <https://www.bloombase.com/content/8936QA88>
2. Bloombase StoreSafe Hardware Compatibility Matrix, <https://www.bloombase.com/content/e8Gzz281>
3. Broadcom Ethernet Network Adapters, <https://www.broadcom.com/products/ethernet-connectivity/network-adapters>
4. Broadcom NetXtreme E-Series P2100G 2x100G PCIe NIC, <https://www.broadcom.com/products/ethernet-connectivity/network-adapters/p2100g>
5. Dell PowerEdge T150 Server, <https://www.dell.com/en-us/work/shop/productdetailstxn/poweredge-t150>
6. Post-Quantum Cryptography, <https://csrc.nist.gov/Projects/post-quantum-cryptography>
7. Marvell/QLogic FastLinQ 45000 Series Ethernet NICs, <https://www.marvell.com/products/ethernet-adapters-and-controllers/45000-ethernet-adapters.html>

Appendix A – Bloombase StoreSafe with Marvell FastLinQ QL45611HLCU

Throughput Tests for Data-at-Rest Encryption over NVMe/RoCE

Read Test

```
Run status group 0 (all jobs):  
  READ: bw=1698KiB/s (1739kB/s), 1698KiB/s-1698KiB/s (1739kB/s-1739kB/s), io=301MiB (316MB), run=181500-181500msec
```

Write Test

```
Run status group 0 (all jobs):  
  WRITE: bw=981MiB/s (1029MB/s), 981MiB/s-981MiB/s (1029MB/s-1029MB/s), io=172GiB (185GB), run=180001-180001msec
```


Throughput Tests for Data-at-Rest Encryption over NVMe/TCP

Read Test

```
Run status group 0 (all jobs):
  READ: bw=704MiB/s (738MB/s), 704MiB/s-704MiB/s (738MB/s-738MB/s), io=124GiB (133GB), run=180001-180001msec
```

Write Test

```
Run status group 0 (all jobs):
  WRITE: bw=812MiB/s (851MB/s), 812MiB/s-812MiB/s (851MB/s-851MB/s), io=143GiB (153GB), run=180001-180001msec
```

Latency Tests for Data-at-Rest Encryption over NVMe/RoCE

Read Test

```
slat (nsec): min=2538, max=39920, avg=4452.80, stdev=2164.45
clat (usec): min=39, max=3182, avg=79.59, stdev=21.61
lat (usec): min=56, max=3188, avg=84.19, stdev=21.75
clat percentiles (usec):
| 1.00th=[ 64], 5.00th=[ 64], 10.00th=[ 65], 20.00th=[ 65],
| 30.00th=[ 65], 40.00th=[ 69], 50.00th=[ 69], 60.00th=[ 70],
| 70.00th=[ 80], 80.00th=[ 104], 90.00th=[ 117], 95.00th=[ 125],
| 99.00th=[ 133], 99.50th=[ 139], 99.90th=[ 143], 99.95th=[ 145],
| 99.99th=[ 151]
bw ( KiB/s): min=46744, max=47624, per=100.00%, avg=47013.48, stdev=133.23, samples=359
iops       : min=11686, max=11906, avg=11753.37, stdev=33.31, samples=359
lat (usec) : 50=0.01%, 100=77.81%, 250=22.19%, 500=0.01%, 750=0.01%
lat (usec) : 1000=0.01%
lat (msec) : 4=0.01%
cpu        : usr=4.02%, sys=8.39%, ctx=2112774, majf=0, minf=12
IO depths  : 1=100.0%, 2=0.0%, 4=0.0%, 8=0.0%, 16=0.0%, 32=0.0%, >=64=0.0%
submit     : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
complete   : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
issued rwts: total=2112768,0,0,0 short=0,0,0,0 dropped=0,0,0,0
latency    : target=0, window=0, percentile=100.00%, depth=1

Run status group 0 (all jobs):
  READ: bw=45.8MiB/s (48.1MB/s), 45.8MiB/s-45.8MiB/s (48.1MB/s-48.1MB/s), io=8253MiB (8654MB), run=180001-180001msec

Disk stats (read/write):
nvme0n1: ios=2111414/0, merge=0/0, ticks=165350/0, in_queue=165350, util=100.00%
```

Write Test

```
slat (nsec): min=2969, max=35346, avg=3823.02, stdev=1055.69
clat (usec): min=26, max=2100.6k, avg=40.72, stdev=1051.90
  lat (usec): min=36, max=2100.6k, avg=44.62, stdev=1051.90
clat percentiles (nsec):
| 1.00th=[38656], 5.00th=[39168], 10.00th=[39168], 20.00th=[39168],
| 30.00th=[39680], 40.00th=[39680], 50.00th=[39680], 60.00th=[39680],
| 70.00th=[39680], 80.00th=[40192], 90.00th=[40704], 95.00th=[42752],
| 99.00th=[54016], 99.50th=[62720], 99.90th=[65280], 99.95th=[66048],
| 99.99th=[68096]
bw ( KiB/s): min= 49, max=91248, per=100.00%, avg=89317.99, stdev=6859.67, samples=357
iops       : min= 12, max=22812, avg=22329.50, stdev=1714.93, samples=357
lat (usec) : 50=98.67%, 100=1.33%, 250=0.01%
lat (msec) : 2=0.01%, 10=0.01%, >=2000=0.01%
cpu        : usr=4.33%, sys=11.36%, ctx=3988629, majf=0, minf=14
IO depths  : 1=100.0%, 2=0.0%, 4=0.0%, 8=0.0%, 16=0.0%, 32=0.0%, >=64=0.0%
  submit   : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
  complete : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
  issued rwts: total=0,3988616,0,0 short=0,0,0,0 dropped=0,0,0,0
  latency   : target=0, window=0, percentile=100.00%, depth=1

Run status group 0 (all jobs):
WRITE: bw=86.6MiB/s (90.8MB/s), 86.6MiB/s-86.6MiB/s (90.8MB/s-90.8MB/s), io=15.2GiB (16.3GB), run=
180001-180001msec
```

Latency Tests for Data-at-Rest Encryption over NVMe/TCP

Read Test

```
slat (nsec): min=3619, max=38848, avg=5442.73, stdev=2372.59
clat (usec): min=94, max=2634, avg=135.81, stdev=27.70
  lat (usec): min=98, max=2639, avg=141.50, stdev=28.37
clat percentiles (usec):
| 1.00th=[ 104], 5.00th=[ 105], 10.00th=[ 106], 20.00th=[ 106],
| 30.00th=[ 108], 40.00th=[ 120], 50.00th=[ 135], 60.00th=[ 151],
| 70.00th=[ 155], 80.00th=[ 167], 90.00th=[ 172], 95.00th=[ 182],
| 99.00th=[ 190], 99.50th=[ 194], 99.90th=[ 208], 99.95th=[ 227],
| 99.99th=[ 249]
bw ( KiB/s): min=23064, max=29232, per=100.00%, avg=27941.67, stdev=2072.45, samples=359
iops       : min= 5766, max= 7308, avg=6985.42, stdev=518.11, samples=359
lat (usec) : 100=0.15%, 250=99.85%, 500=0.01%, 750=0.01%, 1000=0.01%
lat (msec) : 4=0.01%
cpu        : usr=3.43%, sys=5.17%, ctx=1255707, majf=0, minf=10
IO depths  : 1=100.0%, 2=0.0%, 4=0.0%, 8=0.0%, 16=0.0%, 32=0.0%, >=64=0.0%
  submit   : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
  complete : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
  issued rwts: total=1255702,0,0,0 short=0,0,0,0 dropped=0,0,0,0
  latency   : target=0, window=0, percentile=100.00%, depth=1

Run status group 0 (all jobs):
READ: bw=27.2MiB/s (28.6MB/s), 27.2MiB/s-27.2MiB/s (28.6MB/s-28.6MB/s), io=4905MiB (5143MB), run=
180001-180001msec
```

Write Test

```
slat (nsec): min=3428, max=77275, avg=4044.29, stdev=1033.78
clat (usec): min=33, max=7005, avg=54.43, stdev=14.49
  lat (usec): min=51, max=7009, avg=58.63, stdev=14.54
clat percentiles (nsec):
| 1.00th=[46848], 5.00th=[52480], 10.00th=[52480], 20.00th=[52992],
| 30.00th=[53504], 40.00th=[54528], 50.00th=[54528], 60.00th=[54528],
| 70.00th=[54528], 80.00th=[55040], 90.00th=[55040], 95.00th=[55552],
| 99.00th=[69120], 99.50th=[72192], 99.90th=[82432], 99.95th=[83456],
| 99.99th=[91648]
bw ( KiB/s): min=65144, max=73056, per=100.00%, avg=66815.77, stdev=1040.31, samples=359
iops      : min=16286, max=18264, avg=16703.94, stdev=260.08, samples=359
lat (usec) : 50=2.32%, 100=97.68%, 250=0.01%, 500=0.01%
lat (msec)  : 10=0.01%
cpu         : usr=6.08%, sys=8.77%, ctx=3002874, majf=0, minf=12
IO depths   : 1=100.0%, 2=0.0%, 4=0.0%, 8=0.0%, 16=0.0%, 32=0.0%, >=64=0.0%
  submit    : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
  complete  : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
  issued rwts: total=0,3002866,0,0 short=0,0,0,0 dropped=0,0,0,0
  latency   : target=0, window=0, percentile=100.00%, depth=1

Run status group 0 (all jobs):
  WRITE: bw=65.2MiB/s (68.3MB/s), 65.2MiB/s-65.2MiB/s (68.3MB/s-68.3MB/s), io=11.5GiB (12.3GB), run=
180001-180001msec
```