Mellanox OFED Stack for Linux
User's Manual

Rev 1.20

Mellanox OFED Stack for Linux User's Manual

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Revision History

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Rev 1.20 (12-June-2008)

- Added the '--force' flag to the installation script **`mlnxofedinstall`** (see Section 2.3.2 on page 22)

Rev 1.10 (08-April-2008)

- Updated chapters: All
- New chapters: Quality of Service, Diagnostics, Glossary
- Deleted the SRP Target appendix

Rev 1.00 (12-March-2008)

- First release

Preface

This Preface provides general information concerning the scope and organization of this User's Manual. It includes the following sections:

Intended Audience

This manual is intended for system administrators responsible for the installation, configuration, management and maintenance of the software and hardware of InfiniBand adapter cards. It is also intended for and application developers.

Document Organization

Table 1 - Chapters in Brief

Chapter No.	Title	Brief Description
Chapter 1	Mellanox OFED Overview	Provides an overview of the device's interfaces and features
Chapter 2	Installation	Describes the installation and uninstallation procedures
Chapter 3	IPoIB	Describes the IP over IB API installed by Mellanox OFED
Chapter 4	RDS	Describes the Reliable Datagram Sockets API installed by Mellanox OFED
Chapter 5	SDP	Describes the Socket Direct Protocol API installed by Mellanox OFED
Chapter 6	SRP	Describes SRP in general and an SRP Initiator (Host) API that is installed by Mellanox OFED
Chapter 7	MPI	Describes two MPI implementations included in Mellanox OFED
Chapter 8	Quality of Service	Describes Quality of Service over Mellanox OFED
Chapter 9	OpenSM – Subnet Manager	Describes a Subnet Manager that is installed by Mellanox OFED
Appendix A	Boot over IB (BoIB)	Describes the gPXE Boot module included in Mellanox OFED
Appendix B	Performance Troubleshooting	Provides tips for troubleshooting machine performance on the PCI Express and InfiniBand interfaces
Appendix C	ULP Performance Tuning	Provides tips for tuning the performance of ULPs

Documentation Conventions

Typographical Conventions

Table 2 - Typographical Conventions

Description	Convention	Example
File names	`file.extension`	
Directory names	`directory`	
Commands and their parameters	**`command param1`**	
Optional items	`[ ]`	
Mutually exclusive parameters	`{ p1 | p2 | p3 }`	
Optional mutually exclusive parameters	`[ p1 | p2 | p3 ]`	
Prompt of a *user* command under bash shell	`hostname$`	
Prompt of a *root* command under bash shell	`hostname#`	
Prompt of a *user* command under tcsh shell	`tcsh$`	
Environment variables	VARIABLE	
Code example	`if (a==b){};`	
Comment at the beginning of a code line	!, #	
Characters to be typed by users as-is	**bold font**	
Keywords	**bold font**	
Variables for which users supply specific values	*Italic font*	
Emphasized words	*Italic font*	*These are emphasized words*
Pop-up menu sequences	menu1 --> menu2 -->... --> item	
Note	**Note:**	
Warning	**Warning!**	

Common Abbreviations and Acronyms

Table 3 - Abbreviations and Acronyms (Sheet 1 of 2)

Abbreviation / Acronym	Whole Word / Description
B	(Capital) ‘B’ is used to indicate size in bytes or multiples of bytes (e.g., 1KB = 1024 bytes, and 1MB = 1048576 bytes)
b	(Small) ‘b’ is used to indicate size in bits or multiples of bits (e.g., 1Kb = 1024 bits)
FW	Firmware
HCA	Host Channel Adapter
HW	Hardware
IB	InfiniBand

Table 3 - Abbreviations and Acronyms (Sheet 2 of 2)

Abbreviation / Acronym	Whole Word / Description
LSB	Least significant *byte*
lsb	Least significant *bit*
MSB	Most significant *byte*
msb	Most significant bit
SW	Software

Related Documentation

Table 4 - Reference Documents

Document Name	Description
InfiniBand Architecture Specification, Vol. 1, Release 1.2.1	The InfiniBand Architecture Specification that is provided by IBTA
Firmware Release Notes for Mellanox HCA devices	See the Release Notes PDF file relevant to your HCA device under http://www.mellanox.com/support/custom_firmware_table.php
MFT User's Manual	Mellanox Firmware Tools User's Manual. See under `docs/` folder of installed package
MFT Release Notes	Release Notes for the Mellanox Firmware Tools included in the Mellanox OFED for Linux under `docs/`.

Support and Updates Webpage

Please visit http://www.mellanox.com/products/ofed.php for FAQ, troubleshooting, future updates to this manual, etc.

1 Mellanox OFED Overview

1.1 Introduction to Mellanox OFED

Mellanox Technologies offers InfiniBand Host Channel Adapter (HCA) cards with 10, 20, and 40Gb/s InfiniBand ports, and a PCI-X or PCI Express 2.0 (up to 5GT/s) uplink to servers. The cards deliver low-latency and high-bandwidth for performance-driven server and storage clustering applications in Enterprise Data Centers (EDC), High-Performance Computing (HPC), and Embedded environments. All Mellanox adapter cards are compatible with OpenFabrics-based RDMA protocols and software, and are supported with major operating system distributions.

The Mellanox OFED for Linux is a single software stack that operates across all available Mellanox InfiniBand (IB) devices and configurations, supporting the applications described above.

1.2 Mellanox OFED Package

1.2.1 ISO Image

Mellanox OFED for Linux (MLNX_OFED_LINUX) is provided as ISO images, one per a supported Linux distribution, that includes *source code* and *binary* RPMs, firmware, utilities, and documentation. The ISO image contains an installation script (called `mlnxofedinstall`) that performs the necessary steps to accomplish the following:

- Discover the currently installed kernel
- Uninstall any InfiniBand stacks that are part of the standard operating system distribution or another vendor's commercial stack
- Install the MLNX_OFED_LINUX binary RPMs (if they are available for the current kernel)
- Identify the currently installed InfiniBand HCAs and perform the required firmware updates

1.2.2 Software Components

MLNX_OFED_LINUX contains the following software components:

- HCA drivers
  - mthca, mlx4
- Mid-layer core
  - Verbs, MADs, SA, CM, CMA, uVerbs, uMADs
- Upper Layer Protocols (ULPs)
  - IPoIB, RDS, SDP, SRP Initiator
- MPI
  - Open MPI stack supporting the InfiniBand interface
  - OSU MVAPICH stack supporting the InfiniBand interface
  - MPI benchmark tests (OSU BW/LAT, Intel MPI Benchmark, Presta)
- OpenSM: InfiniBand Subnet Manager

- Utilities
  - Diagnostic tools
  - Performance tests
- Firmware tools (MFT)
- Source code for all the OFED software modules (for use under the conditions mentioned in the modules' LICENSE files)
- Documentation

1.2.3 Firmware

The ISO image includes the following firmware items:

- Firmware images (.mlx format) for all Mellanox standard HCA devices
- Firmware configuration (.INI) files for Mellanox standard HCA adapter cards and custom cards
- Boot over IB (gPXE boot) for ConnectX™ IB, InfiniHost™ III Ex in Mem-free mode, and InfiniHost™ III Lx HCA devices

1.2.4 Directory Structure

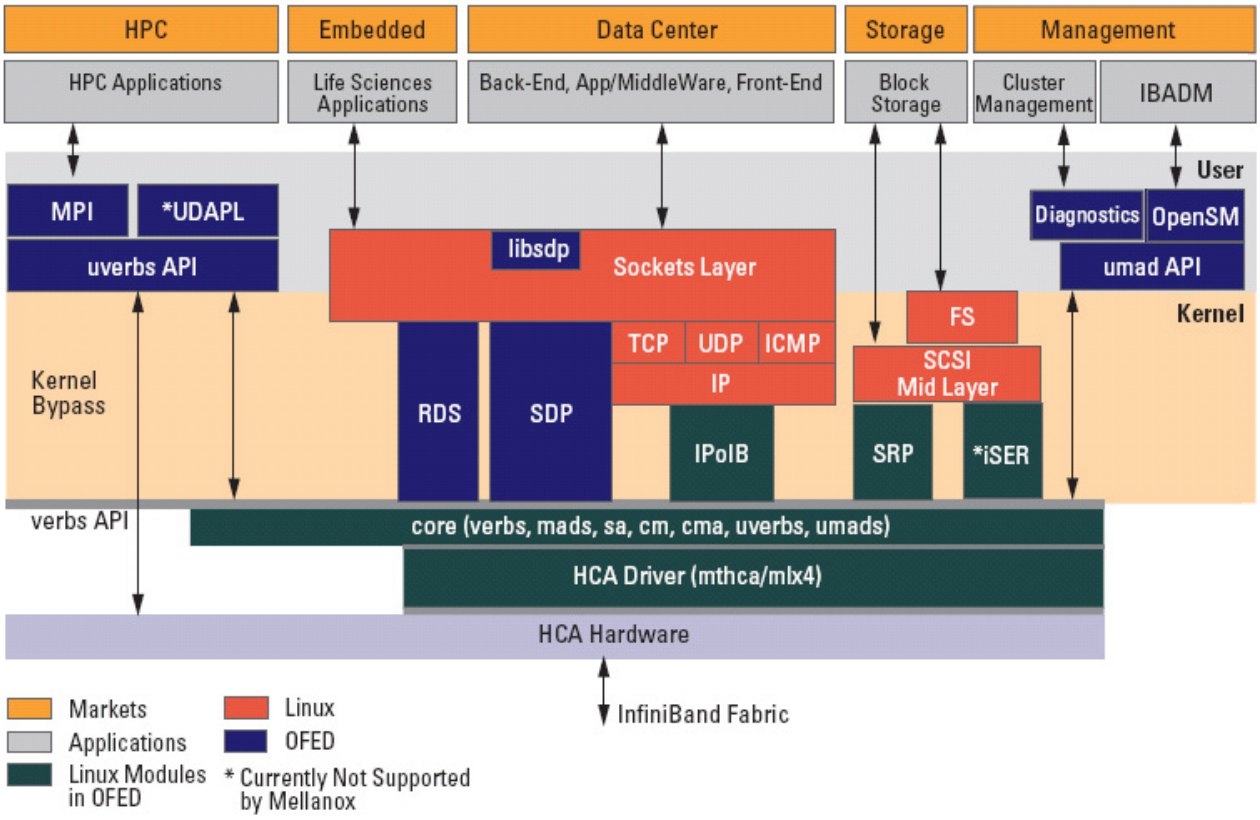
The ISO image of MLNX_OFED_LINUX contains the following files and directories:

- mlnxofedinstall — This is the MLNX_OFED_LINUX installation script.
- uninstall.sh — This is the MLNX_OFED_LINUX un-installation script.
- <CPU architecture folders> — Directory of binary RPMs for a specific CPU architecture.
- firmware/ — Directory of the Mellanox IB HCA firmware images (including Boot-over-IB)
- src/ — Directory of the OFED source tarball and the Mellanox Firmware Tools (MFT) tarball
- docs/ — Directory of Mellanox OFED related documentation

1.3 Architecture

Figure 1 shows a diagram of the Mellanox OFED stack, and how upper layer protocols (ULPs) interface with the hardware and with the kernel and user spaces. The application level also shows the versatility of markets that Mellanox OFED applies to.

Figure 1: Mellanox OFED Stack



The following sub-sections briefly describe the various components of the Mellanox OFED stack.

1.3.1 HCA Drivers

Mellanox OFED includes two drivers for Mellanox HCA hardware: *mthca* and *mlx4*.

mthca

mthca is the low level driver implementation for the following Mellanox Technologies HCA (InfiniBand) devices: InfiniHost, InfiniHost III Ex and InfiniHost III Lx.

mlx4

mlx4 is the low level driver implementation for Mellanox Technologies' ConnectX adapters. The ConnectX can operate as an InfiniBand adapter (HCA).

1.3.2 Mid-layer Core

Core services include: management interface (MAD), connection manager (CM) interface, and Subnet Administrator (SA) interface. The stack includes components for both user-mode and kernel applications. The core services run in the kernel and expose an interface to user-mode for verbs, CM and management.

1.3.3 ULPs

IPoIB

The IP over IB (IPoIB) driver is a network interface implementation over InfiniBand. IPoIB encapsulates IP datagrams over an InfiniBand connected or datagram transport service. IPoIB preappends the IP datagrams with an encapsulation header, and sends the outcome over the InfiniBand transport service. The transport service is Reliable Connected (RC) by default, but it may also be configured to be Unreliable Datagram (UD). The interface supports unicast, multicast and broadcast. For details, see Chapter 3, “IPoIB”.

RDS

Reliable Datagram Sockets (RDS) is a socket API that provides reliable, in-order datagram delivery between sockets over RC or TCP/IP. For more details, see Chapter 4, “RDS”.

SDP

Sockets Direct Protocol (SDP) is a byte-stream transport protocol that provides TCP stream semantics. SDP utilizes InfiniBand's advanced protocol offload capabilities. Because of this, SDP can have lower CPU and memory bandwidth utilization when compared to conventional implementations of TCP, while preserving the TCP APIs and semantics upon which most current network applications depend. For more details, see Chapter 5, “SDP”.

SRP

SRP (SCSI RDMA Protocol) is designed to take full advantage of the protocol offload and RDMA features provided by the InfiniBand architecture. SRP allows a large body of SCSI software to be readily used on InfiniBand architecture. The SRP driver—known as the SRP Initiator—differs from traditional low-level SCSI drivers in Linux. The SRP Initiator does not control a local HBA; instead, it controls a connection to an IO controller—known as the SRP Target—to provide access to remote storage devices across an InfiniBand fabric. The SRP Target resides in an IO unit and provides storage services. See Chapter 6, “SRP”.

1.3.4 MPI

Message Passing Interface (MPI) is a library specification that enables the development of parallel software libraries to utilize parallel computers, clusters, and heterogeneous networks. Mellanox OFED includes the following MPI implementations over InfiniBand:

- Open MPI – an open source MPI-2 implementation by the Open MPI Project
- OSU MVAPICH – an MPI-1 implementation by Ohio State University

Mellanox OFED also includes MPI benchmark tests such as OSU BW/LAT, Intel MPI Benchmark, and Presta.

1.3.5 InfiniBand Subnet Manager

All InfiniBand-compliant ULPs require a proper operation of a Subnet Manager (SM) running on the InfiniBand fabric, at all times. An SM can run on any node or on an IB switch. OpenSM is an InfiniBand-compliant Subnet Manager, and it is installed as part of Mellanox OFED.[1] See Chapter 9, “OpenSM – Subnet Manager”.

1. OpenSM is disabled by default. See Chapter 9, “OpenSM – Subnet Manager” for details on enabling it.

1.3.6 Diagnostic Utilities

Mellanox OFED includes the following two diagnostic packages for use by network and data-center managers:

- ibutils – Mellanox Technologies diagnostic utilities
- infiniband-diags – OpenFabrics Alliance InfiniBand diagnostic tools

1.3.7 Performance Utilities

A collection of tests written over uverbs intended for use as a performance micro-benchmark. As an example, the tests can be used for hardware or software tuning and/or functional testing. See `PERF_TEST_README.txt` under `docs/`.

1.3.8 Mellanox Firmware Tools

The Mellanox Firmware Tools (MFT) package is a set of firmware management tools for a single InfiniBand node. MFT can be used for:

- Generating a standard or customized Mellanox firmware image
- Querying for firmware information
- Burning a firmware image to a single InfiniBand node

MFT includes the following tools:

`mlxburn`

This tool provides the following functions:

- Generation of a standard or customized Mellanox firmware image for burning (in binary or .mlx format)
- Burning an image to the Flash/EEPROM attached to a Mellanox HCA or switch device
- Querying the firmware version loaded on an HCA board
- Displaying the VPD (Vital Product Data) of an HCA board

`flint`

This tool burns a firmware binary image to the Flash(es) attached to an HCA board. It includes query functions to the burnt firmware image and to the binary image file.

`spark`

This tool burns a firmware binary image to the EEPROM(s) attached to a switch device. It includes query functions to the burnt firmware image and to the binary image file. The tool accesses the EEPROM and/or switch device via an I2C-compatible interface.

`ibspark`

This tool burns a firmware binary image to the EEPROM(s) attached to a switch device. It includes query functions to the burnt firmware image and to the binary image file. The tool accesses the switch device and the EEPROM via vendor-specific MADs over the InfiniBand fabric (In-Band tool).

`Debug utilities`

A set of debug utilities (e.g., itrace, mstdump, isw, and i2c)

For additional details, please refer to the MFT User's Manual `docs/`.

1.4 Quality of Service

Quality of Service (QoS) requirements stem from the realization of I/O consolidation over an IB network. As multiple applications and ULPs share the same fabric, a means is needed to control their use of network resources.

QoS over Mellanox OFED for Linux is discussed in Chapter 9, “OpenSM – Subnet Manager”.

2 Installation

This chapter describes how to install and test the Mellanox OFED for Linux package on a single host machine with Mellanox InfiniBand hardware installed. The chapter includes the following sections:

2.1 Hardware and Software Requirements

2.1.1 Hardware Requirements

Platforms

- A server platform with an adapter card based on one of the following Mellanox Technologies' InfiniBand HCA devices:
  - ConnectX™ IB (firmware: fw-25408)
  - InfiniHost™ III Ex (firmware: fw-25218 for Mem-Free cards, and fw-25208 for cards with memory)
  - InfiniHost™ III Lx (firmware: fw-25204)
  - InfiniHost™ (firmware: fw-23108)

Note: For the list of supported architecture platforms, please refer to the *Mellanox OFED Release Notes* file.

Required Disk Space for Installation

- 400 MB

2.1.2 Software Requirements

Operating System

- Linux operating system

Note: For the list of supported operating system distributions and kernels, please refer to the *Mellanox OFED Release Notes* file.

Installer Privileges

- The installation requires administrator privileges on the target machine

2.2 Downloading Mellanox OFED

Step 1. Verify that the system has a Mellanox HCA installed by ensuring that you can see ConnectX or InfiniHost entries in the display.

The following example shows a system with an installed Mellanox HCA:

```
host1# lspci -v | grep Mellanox
06:01.0 PCI bridge: Mellanox Technologies MT23108 PCI Bridge (rev
a0) (prog-if 00[Normal decode])
07:00.0 InfiniBand: Mellanox Technologies MT23108 InfiniHost (rev
a0)
Subsystem: Mellanox Technologies MT23108 InfiniHost
```

Step 2. Download the ISO image to your host.

The image's name has the format MLNX_OFED_LINUX-<ver>-<OS label>.iso. You can download it from http://www.mellanox.com/ under Mellanox OFED.

Step 3. Use the md5sum utility to confirm the file integrity of your ISO image. Run the following command and compare the result to the value provided on the download page.

```
host1$ md5sum MLNX_OFED_LINUX-<ver>-<OS label>.iso
```

2.3 Installing Mellanox OFED

The installation script, `mlnxofedinstall`, performs the following:

- Discovers the currently installed kernel
- Uninstalls any InfiniBand stacks that are part of the standard operating system distribution or another vendor's commercial stack
- Installs the MLNX_OFED_LINUX binary RPMs (if they are available for the current kernel)
- Identifies the currently installed InfiniBand HCAs and automatically[1] upgrades the firmware

2.3.1 Pre-installation Notes

- The installation script removes all previously installed Mellanox OFED packages and re-installs from scratch. You will be prompted to acknowledge the deletion of the old packages.

  Note: Pre-existing configuration files will be saved with the extension ".conf.saverpm".

- If you need to install Mellanox OFED on an entire (homogeneous) cluster, a common strategy is to mount the ISO image on one of the cluster nodes and then copy it to a shared file system such as NFS. To install on all the cluster nodes, use cluster-aware tools (such as pdsh).

2.3.2 Installation Script

Mellanox OFED includes an installation script called `mlnxofedinstall`. Its usage is described below. You will use it during the installation procedure described in Section 2.3.3, "Installation Procedure," on page 23.

1. The firmware will not be updated if you run the install script with the '--without-fw-update' option.

Usage

```
./mlnxofedinstall [OPTIONS]
```

Note: If no options are provided to the script, then all available RPMs are installed.

Options

```
-c|--config <packages config_file>
                    Example of the configuration file can be found under
                    docs
-n|--net <network config file>
                    Example of the network configuration file can be
                    found under docs
-p|--print-available Print available packages for the current platform
                    and create a corresponding ofed.conf file. The
                    installation script exits after creating ofed.conf.
--with-32bit        Install 32-bit libraries (default). This is relevant
                    for x86_64 and ppc64 platforms.
--without-32bit     Skip 32-bit libraries installation.
--without-depcheck  Skip Distro's libraries check
--without-fw-update Skip firmware update
--force-fw-update   Force firmware update
--force             Force installation (without querying the user)
--all|--hpc|--basic Install all, hpc or basic packages respectively
-v|-vv|-vvv         Set verbosity level
-q                  Set quiet - no messages will be printed
```

2.3.3 Installation Procedure

Step 1. Login to the installation machine as root.

Step 2. Mount the ISO image on your machine

```
host1# mount -o ro,loop MLNX_OFED_LINUX-<ver>-<OS label>.iso /mnt
```

Note: After mounting the ISO image, `/mnt` will be a Read Only folder.

Step 3. Run the installation script

```
host1# /mnt/mlnxofedinstall
    This program will install the MLNX_OFED_LINUX package on your machine.
    Note that all other Mellanox, OEM, OFED, or Distribution IB packages will be
    removed.
    Do you want to continue?[y/N]:y

    Uninstalling the previous version of OFED

    Starting MLNX_OFED_LINUX installation

    Installing kernel-ib RPM
    Preparing...                ########################################### [100%]
```

```
   1:kernel-ib              ########################################### [100%]
Installing kernel-ib-devel RPM
Preparing...                ########################################### [100%]
   1:kernel-ib-devel        ########################################### [100%]
Installing ib-bonding RPM
Preparing...                ########################################### [100%]
   1:ib-bonding             ########################################### [100%]
Installing mft RPM
Preparing...                ########################################### [100%]
   1:mft                    ########################################### [100%]
Install user level RPMs:
Preparing...                ########################################### [100%]
   1:libibverbs             ###########################################  [  1%]
   2:libibcommon            ###########################################  [  3%]
   3:libibumad              ###########################################  [  4%]
   4:libibcommon            ###########################################  [  6%]
   5:libibumad              ###########################################  [  7%]
   6:libibverbs             ###########################################  [  9%]
   7:opensm-libs            ###########################################  [ 10%]
   8:libibmad               ###########################################  [ 12%]
   9:libibverbs-devel       ###########################################  [ 13%]
  10:librdmacm              ###########################################  [ 14%]
  11:opensm-libs            ###########################################  [ 16%]
  12:libmthca               ###########################################  [ 17%]
  13:libmlx4                ###########################################  [ 19%]
  14:libibcm                ###########################################  [ 20%]
  15:libibcommon-devel      ###########################################  [ 22%]
  16:libibumad-devel        ###########################################  [ 23%]
  17:libibmad               ###########################################  [ 25%]
  18:librdmacm              ###########################################  [ 26%]
  19:mpi-selector           ###########################################  [ 28%]
  20:libsdp                 ###########################################  [ 29%]
  21:mvapich_gcc            ###########################################  [ 30%]
  22:openmpi_gcc            ###########################################  [ 32%]
  23:ofed-scripts           ###########################################  [ 33%]
  24:libibverbs-devel       ###########################################  [ 35%]
  25:libibverbs-devel-static###########################################  [ 36%]
  26:libibverbs-devel-static###########################################  [ 38%]
  27:libibverbs-utils       ###########################################  [ 39%]
  28:libmthca               ###########################################  [ 41%]
  29:libmthca-devel-static  ###########################################  [ 42%]
  30:libmthca-devel-static  ###########################################  [ 43%]
  31:libmlx4                ###########################################  [ 45%]
  32:libmlx4-devel-static   ###########################################  [ 46%]
  33:libmlx4-devel-static   ###########################################  [ 48%]
  34:libibcm                ###########################################  [ 49%]
  35:libibcm-devel          ###########################################  [ 51%]
  36:libibcm-devel          ###########################################  [ 52%]
  37:libibcommon-devel      ###########################################  [ 54%]
  38:libibcommon-static     ###########################################  [ 55%]
```

```
  39:libibcommon-static     ########################################### [ 57%]
  40:libibumad-devel        ########################################### [ 58%]
  41:libibumad-static       ########################################### [ 59%]
  42:libibumad-static       ########################################### [ 61%]
  43:libibmad-devel         ########################################### [ 62%]
  44:libibmad-devel         ########################################### [ 64%]
  45:libibmad-static        ########################################### [ 65%]
  46:libibmad-static        ########################################### [ 67%]
  47:ibsim                  ########################################### [ 68%]
  48:librdmacm-utils        ########################################### [ 70%]
  49:librdmacm-devel        ########################################### [ 71%]
  50:librdmacm-devel        ########################################### [ 72%]
  51:libsdp                 ########################################### [ 74%]
  52:libsdp-devel           ########################################### [ 75%]
  53:libsdp-devel           ########################################### [ 77%]
  54:opensm                 ########################################### [ 78%]
  55:opensm-devel           ########################################### [ 80%]
  56:opensm-devel           ########################################### [ 81%]
  57:opensm-static          ########################################### [ 83%]
  58:opensm-static          ########################################### [ 84%]
  59:perftest               ########################################### [ 86%]
  60:mstflint               ########################################### [ 87%]
  61:sdpnetstat             ########################################### [ 88%]
  62:srptools               ########################################### [ 90%]
  63:rds-tools              ########################################### [ 91%]
  64:ibutils                ########################################### [ 93%]
  65:infiniband-diags       ########################################### [ 94%]
  66:qperf                  ########################################### [ 96%]
  67:ofed-docs              ########################################### [ 97%]
  68:mpitests_mvapich_gcc   ########################################### [ 99%]
  69:mpitests_openmpi_gcc   ########################################### [100%]

Installation finished successfully.
Programming HCA firmware...
Device: /dev/mst/mt25418_pci_cr0
Running: mlxburn -d /dev/mst/mt25418_pci_cr0 -fw ./firmware/fw-25408/fw-25408-
rel.mlx -no
-I- Image burn completed successfully.
Please reboot your system for the changes to take effect.
```

Note: In case your machine has an unsupported HCA device, no firmware update will occur and the error message below will be printed. Please contact your hardware vendor for help on firmware updates.

Error message:

```
-I- Querying device ...
-E- Can't auto detect fw configuration file: ...
```

Step 4. In case the installation script performed firmware updates to InfiniBand hardware, it will ask you to reboot your machine.

Step 5. The script adds the following lines to `/etc/security/limits.conf` for the userspace components such as MPI:

```
* soft memlock unlimited
* hard memlock unlimited
```

These settings unlimit the amount of memory that can be pinned by a user space application. If desired, tune the value unlimited to a specific amount of RAM.

Step 6. For your machine to be part of the InfiniBand fabric, a Subnet Manager must be running on one of the fabric nodes. At this point, Mellanox OFED for Linux has already installed the OpenSM Subnet Manager on your machine. For details on starting OpenSM, see Chapter 9, "OpenSM – Subnet Manager".

Step 7. Run the `hca_self_test.ofed` utility to verify whether or not the InfiniBand link is up. The utility also checks for and displays additional information such as

- HCA firmware version
- Kernel architecture
- Driver version
- Number of active HCA ports along with their states
- Node GUID

Note: For more details on `hca_self_test.ofed`, see the file `hca_self_test.readme` under `docs/`.

```
host1# /usr/bin/hca_self_test.ofed

---- Performing InfiniBand HCA Self Test ----
Number of HCAs Detected ................ 1
PCI Device Check ....................... PASS
Kernel Arch ............................ x86_64
Host Driver Version .................... OFED-1.3 1.3-2.6.9_42.ELsmp
Host Driver RPM Check .................. PASS
HCA Firmware on HCA #0 ................. 2.3.0
HCA Firmware Check on HCA #0 ........... PASS
Host Driver Initialization ............. PASS
Number of HCA Ports Active ............. 0
Port State of Port #0 on HCA #0 ........ INIT
Port State of Port #0 on HCA #0 ........ DOWN
Error Counter Check on HCA #0 .......... PASS
Kernel Syslog Check .................... PASS
Node GUID on HCA #0 .................... 00:02:c9:03:00:00:10:e0
------------------ DONE ----------------------
```

Note: After the installer completes, information about the Mellanox OFED installation such as prefix, kernel version, and installation parameters can be retrieved by running the command `/etc/infiniband/info`.

2.3.4 Installation Results

Software

- The OFED and MFT packages are installed under the /usr directory.
- The kernel modules are installed under:
  - InfiniBand subsystem:
    `/lib/modules/`uname -r`/updates/kernel/drivers/infiniband/`
  - mlx4 driver:
    `/lib/modules/`uname -r`/updates/kernel/drivers/net/mlx4/mlx4_core.ko`
  - RDS:
    `/lib/modules/`uname -r`/updates/kernel/net/rds/rds.ko`
  - Bonding module:
    `/lib/modules/`uname -r`/updates/kernel/drivers/net/bonding/bonding.ko`
- The package kernel-ib-devel include files are placed under `/usr/src/ofa_kernel/include/`. These include files should be used when building kernel modules that use the stack. (Note that the include files, if needed, are "backported" to your kernel.)
- The raw package (un-backported) source files are placed under `/usr/src/ofa_kernel-<ver>`
- The script `openibd` is installed under `/etc/init.d/`. This script can be used to load and unload the software stack.
- The directory `/etc/infiniband` is created with the files `info` and `openib.conf`. The `info` script can be used to retrieve Mellanox OFED installation information. The `openib.conf` file contains the list of modules that are loaded when the `openibd` script is used.
- The file `90-ib.rules` is installed under `/etc/udev/rules.d/`
- The file `/etc/modprobe.conf` is updated to include the following:
  - **`alias ib<n> ib_ipoib`** (for each ib<n> interface)
  - **`alias net-pf-27 ib_sdp`** (for SDP)
- If OpenSM is installed, the daemon `opensmd` is installed under `/etc/init.d/` and `opensm.conf` is installed under `/etc`.
- If IPoIB configuration files are included, `ifcfg-ib<n>` files will be installed under:
  - `/etc/sysconfig/network-scripts/` on a RedHat machine
  - `/etc/sysconfig/network/` on a SuSE machine
- The installation process unlimits the amount of memory that can be pinned by a user space application. See Step 5.
- Man pages will be installed under `/usr/share/man/`

Firmware

- The firmware of existing HCA devices will be updated if the following two conditions are fulfilled:
  1. You run the installation script in default mode; that is, *without* the option '--without-fw-update'.
  2. The firmware version of the HCA device is older than the firmware version included with the Mellanox OFED ISO image

Note: If an HCA's Flash was originially programmed with an Expansion ROM image, the automatic firmware update will also burn an Expansion ROM image.

- In case your machine has an unsupported HCA device, no firmware update will occur and the error message below will be printed. Please contact your hardware vendor for help on firmware updates.

  Error message:

```
-I- Querying device ...
-E- Can't auto detect fw configuration file: ...
```

2.3.5 Post-installation Notes

- Most of the Mellanox OFED components can be configured or reconfigured after the installation by modifying the relevant configuration files. See the relevant chapters in this manual for details.
- The list of the modules that will be loaded automatically upon boot can be found in the `/etc/infiniband/openib.conf` file.

2.4 Updating Firmware After Installation

In case you ran the `mlnxofedinstall` script with the '`--without-fw-update`' option and now you wish to (manually) update firmware on you adapter card(s), you need to perform the following steps:

Note: If you need to burn an Expansion ROM image, please refer to "Burning the Expansion ROM Image" on page 114.

Note: The following steps are also appropriate in case you wish to burn newer firmware that you have downloaded from Mellanox Technologies' Web site (http://www.mellanox.com/support/firmware_download.php).

Step 1. Start `mst`.

```
host1# mst start
```

Step 2. Identify your target InfiniBand device for firmware update.

a. Get the list of InfiniBand device names on your machine.

```
host1# mst status
MST modules:
------------
    MST PCI module loaded
    MST PCI configuration module loaded
    MST Calibre (I2C) module is not loaded

MST devices:
------------
/dev/mst/mt25418_pciconf0        - PCI configuration cycles access.
                                   bus:dev.fn=02:00.0 addr.reg=88 data.reg=92
                                   Chip revision is: A0
/dev/mst/mt25418_pci_cr0         - PCI direct access.
                                   bus:dev.fn=02:00.0 bar=0xdef00000 size=0x100000
                                   Chip revision is: A0
```

```
/dev/mst/mt25418_pci_msix0      - PCI direct access.
                                  bus:dev.fn=02:00.0 bar=0xdeefe000 size=0x2000
/dev/mst/mt25418_pci_uar0       - PCI direct access.
                                  bus:dev.fn=02:00.0 bar=0xdc800000 size=0x800000
```

b. Your InfiniBand device is the one with the postfix "_pci_cr0". In the example listed above, this will be `/dev/mst/mt25418_pci_cr0`.

Step 3. Burn firmware.

a. Burning a firmware binary image using **`mstflint`** (that is already installed on your machine).

Please refer to `MSTFLINT_README.txt` under `docs/`.

b. Burning a firmware image from a .mlx file using the **`mlxburn`** utility (that is already installed on your machine).

The following command burns firmware onto the ConnectX IB device with the device name obtained in the example of Step 2.

```
host1$ mlxburn -dev /dev/mst/mt25418_pci_cr0 \
-fw /mnt/firmware/fw-25408/fw-25408-rel.mlx
```

Warning! Make sure that you have the correct *device name*, *firmware path*, and *firmware file name* before running this command. For help, please refer to the *Mellanox Firmware Tools (MFT) User's Manual* under `/mnt/docs/`.

Step 3. Reboot your machine after the firmware burning is completed.

2.5 Uninstalling Mellanox OFED

Use the script `/usr/sbin/ofed_uninstall.sh`. to uninstall the Mellanox OFED package. The script is part of the `ofed-scripts` RPM.

3 IPoIB

3.1 Introduction

The IP over IB (IPoIB) driver is a network interface implementation over InfiniBand. IPoIB encapsulates IP datagrams over an InfiniBand Connected or Datagram transport service. This chapter describes the following:

- IPoIB Configuration (Section 3.2)
- How to manually configure IPoIB (Section 3.3)
- How to create and remove subinterfaces (Section 3.4)
- How to verify IPoIB functionality (Section 3.5)
- The ib-bonding driver (Section 3.6)
- How to test IPoIB performance (Section 3.7)

3.2 IPoIB Configuration

Configuring IPoIB is done automatically by the installation script – see Section 2.3. The Configuration of IPoIB requires assigning an IP address and a subnet mask to each HCA port. The first HCA port on the first HCA in the host is called interface ib0, the second port is called ib1, and so on. It is also possible to manually configure IPoIB. This is described in Section 3.3.

An IPoIB configuration can be based on DHCP (by default) or on a static configuration that you need to supply.

3.2.1 IPoIB Configuration Based on DHCP

By default, the installation script uses an IPoIB interface configuration based on DHCP. Mellanox OFED's IPoIB configuration assumes DHCP v3.1.1rc1 (which is available for download via www.ics.org).

Note: A special patch for DHCP is required for supporting IPoIB. The patch for DHCP v3.1.1rc1, `dhcp.patch`, is available under the `docs/` directory.

Standard DHCP fields holding MAC addresses are not large enough to contain an IPoIB hardware address. To overcome this problem, DHCP over InfiniBand messages convey a client identifier field used to identify the DHCP session. This client identifier field can be used to associate an IP address with a client identifier value, such that the DHCP server will grant the same IP address to any client that conveys this client identifier.

Note: Refer to the DHCP documentation for more details how to make this association.

The length of the client identifier field is not fixed in the specification. For Mellanox OFED for Linux, it is recommended to have IPoIB use the same format that Boot over IB uses for this client identifier – see Section A.6.1, "Configuring the DHCP Server," on page 115.

3.2.1.1 DHCP Server

In order for the DHCP server to provide configuration records for clients, an appropriate configuration file, `dhcpd.conf`, must be created and put under `/etc`. See an example under the `docs/` of the Mellanox OFED installation.

The DHCP server must run on a machine which has loaded the IPoIB module.

To run the DHCP server from the command line, enter:

```
dhcpd <IB network interface name> -d
```

Example:

```
host1# dhcpd ib0 -d
```

3.2.1.2 DHCP Client

In order to use a DHCP client identifier, you need to first create a configuration file that defines the DHCP client identifier. Then run the DHCP client with this file using the following command:

```
dhclient –cf <client conf file> <IB network interface name>
```

Example:

The following configuration file defines a DHCP client identifier that has the format that Boot over IB uses.

dhclient.conf:

```
# The value indicates a hexadecimal number
interface "ib1" {
send dhcp-client-identifier 20:00:55:04:01:fe:80:00:00:00:00:00:00:02:c9:02:00:23:13:92;
}
```

In order to use the configuration file, run:

```
host1# dhclient –cf dhclient.conf ib1
```

3.2.2 Static IPoIB Configuration

If you wish to use an IPoIB configuration that is not based on DHCP, you need to supply the installation script with a configuration file (using the ‘-n’ option) containing the full IP configuration. The IPoIB configuration file can specify either or both of the following data for an IPoIB interface:

- A static IPoIB configuration
- An IPoIB configuration based on an Ethernet configuration

Note: See your Linux distribution documentation for additional information about configuring IP addresses.

The following code lines are an excerpt from a sample IPoIB configuration file:

```
# Static settings; all values provided by this file
IPADDR_ib0=11.4.3.175
```

```
NETMASK_ib0=255.255.0.0
NETWORK_ib0=11.4.0.0
BROADCAST_ib0=11.4.255.255
ONBOOT_ib0=1
# Based on eth0; each '*' will be replaced with a corresponding octet
# from eth0.
LAN_INTERFACE_ib0=eth0
IPADDR_ib0=11.4.'*'.'*'
NETMASK_ib0=255.255.0.0
NETWORK_ib0=11.4.0.0
BROADCAST_ib0=11.4.255.255
ONBOOT_ib0=1
# Based on the first eth<n> interface that is found (for n=0,1,...);
# each '*' will be replaced with a corresponding octet from eth<n>.
LAN_INTERFACE_ib0=
IPADDR_ib0=11.4.'*'.'*'
NETMASK_ib0=255.255.0.0
NETWORK_ib0=11.4.0.0
BROADCAST_ib0=11.4.255.255
ONBOOT_ib0=1
```

3.2.3 IPoIB Mode Configuration

IPoIB can run in two modes of operation: Connected mode and Datagram mode. By default, IPoIB is configured to work in Connected mode. This can be changed to become Datagram mode by editing the file `/etc/infiniband/openib.conf` and setting 'SET_IPOIB_CM=no'.

After changing the mode, you need to restart the driver by running:

```
/etc/init.d/openibd restart
```

It is also possible to change the mode of operation on the fly as described below.

Note: `ib0` is used as an example of an IB interface.

To set the Datagram mode of operation, run:

```
echo datagram > /sys/class/net/ib0/mode
```

To set the Connected mode of operation, run:

```
echo connected > /sys/class/net/ib0/mode
```

3.3 Manually Configuring IPoIB

To manually configure IPoIB for the default IB partition, perform the following steps:

Step 1. To configure the interface, enter the **`ifconfig`** command with the following items:

- The appropriate IB interface (ib0, ib1, etc.)

- The IP address that you want to assign to the interface
- The netmask keyword
- The subnet mask that you want to assign to the interface

The following example shows how to configure an IB interface:

```
host1$ ifconfig ib0 11.4.3.175 netmask 255.255.0.0
```

Step 2. (Optional) Verify the configuration by entering the **ifconfig** command with the appropriate interface identifier *ib#* argument.

The following example shows how to verify the configuration:

```
host1$ ifconfig ib0
b0  Link encap:UNSPEC  HWaddr 80-00-04-04-FE-80-00-00-00-00-00-00-
00-00-00-00
inet addr:11.4.3.175  Bcast:11.4.255.255  Mask:255.255.0.0
UP BROADCAST MULTICAST  MTU:65520  Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:128
RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
```

Step 3. Repeat Step 1 and Step 2 on the remaining interface(s).

3.4 Subinterfaces

You can create subinterfaces for a primary IPoIB interface to provide traffic isolation. Each such subinterface (also called a child interface) has a different IP and network addresses from the primary (parent) interface. The default Partition Key (PKey), ff:ff, applies to the primary (parent) interface.

This section describes how to

- Create a subinterface (Section 3.4.1)
- Remove a subinterface (Section 3.4.2)

3.4.1 Creating a Subinterface

To create a child interface (subinterface), follow this procedure:

Note: In the following procedure, `ib0` is used as an example of an IB subinterface.

Step 1. Decide on the PKey to be used in the subnet. Valid values are 0-255. The actual PKey used is a 16-bit number with the most significant bit set. For example, a value of 0 will give a PKey with the value 0x8000.

Step 2. Create a child interface by running:

```
host1$ echo <PKey> > /sys/class/net/<IB subinterface>/create_child
```

```
Example:
host1$ echo 0 > /sys/class/net/ib0/create_child
```

This will create the interface ib0.8000.

Step 3. Verify the configuration of this interface by running:

host1$ ifconfig <subinterface>.<subinterface PKey>

Using the example of Step 2:

```
host1$ ifconfig ib0.8000
ib0.8000  Link encap:UNSPEC  HWaddr 80-00-00-4A-FE-80-00-00-00-00-00-00-00-00-00-00
BROADCAST MULTICAST  MTU:2044  Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:128
RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
```

Step 4. As can be seen, the interface does not have IP or network addresses. To configure those, you should follow the manual configuration procedure described in Section 3.3.

Step 5. To be able to use this interface, a configuration of the Subnet Manager is needed so that the PKey chosen, which defines a broadcast address, be recognized (see Chapter 9, "OpenSM – Subnet Manager").

3.4.2 Removing a Subinterface

To remove a child interface (subinterface), run:

echo <subinterface PKey> /sys/class/net/<ib_interface>/delete_child

Using the example of Step 2:

echo 0x8000 > /sys/class/net/ib0/delete_child

Note that when deleting the interface you must use the PKey value with the most significant bit set (e.g., 0x8000 in the example above).

3.5 Verifying IPoIB Functionality

To verify your configuration and your IPoIB functionality, perform the following steps:

Step 1. Verify the IPoIB functionality by using the **ifconfig** command.

The following example shows how two IB nodes are used to verify IPoIB functionality. In the following example, IB node 1 is at 11.4.3.175, and IB node 2 is at 11.4.3.176:

```
host1# ifconfig ib0 11.4.3.175 netmask 255.255.0.0
host2# ifconfig ib0 11.4.3.176 netmask 255.255.0.0
```

Step 2. Enter the ping command from 11.4.3.175 to 11.4.3.176.

The following example shows how to enter the ping command:

```
host1# ping -c 5 11.4.3.176
PING 11.4.3.176 (11.4.3.176) 56(84) bytes of data.
64 bytes from 11.4.3.176: icmp_seq=0 ttl=64 time=0.079 ms
64 bytes from 11.4.3.176: icmp_seq=1 ttl=64 time=0.044 ms
64 bytes from 11.4.3.176: icmp_seq=2 ttl=64 time=0.055 ms
64 bytes from 11.4.3.176: icmp_seq=3 ttl=64 time=0.049 ms
64 bytes from 11.4.3.176: icmp_seq=4 ttl=64 time=0.065 ms
--- 11.4.3.176 ping statistics ---
```

```
5 packets transmitted, 5 received, 0% packet loss, time 3999ms rtt
min/avg/max/mdev = 0.044/0.058/0.079/0.014 ms, pipe 2
```

3.6 The ib-bonding Driver

The ib-bonding driver is a High Availability solution for IPoIB interfaces. It is based on the Linux Ethernet Bonding Driver and was adapted to work with IPoIB. The ib-bonding package contains a bonding driver and a utility called ib-bond to manage and control the driver operation.

The ib-bonding driver comes with the ib-bonding package (run "`rpm -qi ib-bonding`" to get the package information).

3.6.1 Using the ib-bonding Driver

The ib-bonding driver can be loaded manually or automatically.

Manual Operation

Use the utility `ib-bond` to start, query, or stop the driver. For details on this utility, please read the documentation for the ib-bonding package under

`/usr/share/doc/ib-bonding-0.9.0/ib-bonding.txt` on RedHat, and

`/usr/share/doc/packages/ib-bonding-0.9.0/ib-bonding.txt` on SuSE.

Automatic Operation

There are two ways to configure automatic ib-bonding operation:

1. Using the openibd configuration file, as described in the following steps:
   a. Edit the file `/etc/infiniband/openib.conf` to define bonding parameters.
   Example:

```
# Enable the bonding driver on startup.
IPOIBBOND_ENABLE=yes
# # Set bond interface names
IPOIB_BONDS=bond0,bond8007
# Set specific bond params; address and slaves
bond0_IP=10.10.10.1/24
bond0_SLAVES=ib0,ib1
bond8007_IP=20.10.10.1
bond1_SLAVES=ib0.8007,ib1.8007
```

   b. Restart the driver by running:

```
/etc/init.d/openibd restart
```

2. Using a standard OS bonding configuration. For details on this, please read the documentation for the ib-bonding package under

   `/usr/share/doc/ib-bonding-0.9.0/ib-bonding.txt` on RedHat, and

   `/usr/share/doc/packages/ib-bonding-0.9.0/ib-bonding.txt` on SuSE.

Notes

- If the bondX name is defined but one of bondX_SLAVES or bondX_IPs is missing, then that specific bond will not be created.
- The bondX name must not contain characters which are disallowed for bash variable names such as '.' and '-'.
- Using `/etc/infiniband/openib.conf` to create a persistent configuration is not recommended. Do not use it unless you have no other option. It is not guaranteed that the first method will be supported in future versions of OFED.

3.7 Testing IPoIB Performance

This section describes how to verify IPoIB performance by running the Bandwidth (BW) test and the Latency test. These tests are described in detail at the following URL:

http://www.netperf.org/netperf/training/Netperf.html

Note: For UDP best performance, please use IPoIB in Datagram mode and *not* in Connected mode.

To verify IPoIB performance, perform the following steps:

Step 1. Download Netperf from the following URL:
http://www.netperf.org/netperf/NetperfPage.html

Step 2. Compile Netperf by following the instructions at
http://www.netperf.org/netperf/NetperfPage.html.

Step 3. Start the Netperf server.
The following example shows how to start the Netperf server:

```
host1$ netserver
Starting netserver at port 12865
Starting netserver at hostname 0.0.0.0 port 12865 and family
AF_UNSPEC
host1$
```

Step 4. Run the Netperf client. The default test is the Bandwidth test.
The following example shows how to run the Netperf client, which starts the Bandwidth test by default:

```
host2$ netperf -H 11.4.17.6 -t TCP_STREAM -c -C -- -m 65536
TCP STREAM TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET to 11.4.17.6
(11.4.17.6) port 0 AF_INET
Recv   Send    Send                          Utilization       Service Demand
Socket Socket  Message  Elapsed              Send     Recv     Send    Recv
Size   Size    Size     Time     Throughput  local    remote   local   remote
bytes  bytes   bytes    secs.    10^6bits/s  % S      % S      us/KB   us/KB

 87380  16384  65536    10.00      2483.00   7.03     5.42     1.854   1.431
```

Note: You must specify the IPoIB IP address when running the Netperf client.

The following table describes parameters for the netperf command:

Option	Description
-H	Where to find the server
11.4.17.6	IPoIB IP address
-t <Test Name>	Specify the test to perform. Options are TCP_STREAM, TCP_RR, etc.
-c	Client CPU utilization
-C	Server CPU utilization
--	Separates the global and test-specific parameters
-m	Message size, which is 65536 in the example above

Note that the run example above produced the following results:

- Throughput is 2.483 gigabits per second
- Client CPU utilization is 7.03 percent of client CPU
- Server CPU utilization is 5.42 percent of server CPU

Step 5. Run the Netperf Latency test.

Run the test once, and stop the server so that it does not repeat the test.

The following example shows how to run the Latency test, and then stop the Netperf server:

```
host2$ netperf -H 11.4.17.6 -t TCP_RR -c -C -- -r1,1
TCP REQUEST/RESPONSE TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET to 11.4.17.6
(11.4.17.6) port 0 AF_INET
Local /Remote
Socket Size   Request Resp.  Elapsed Trans.   CPU    CPU    S.dem   S.dem
Send   Recv   Size    Size   Time    Rate     local  remote local   remote
bytes  bytes  bytes   bytes  secs.   per sec  % S    % S    us/Tr   us/Tr

16384  87380  1       1      10.00   19913.18  5.61   6.79   22.549  27.296
16384  87380
```

The following table describes parameters for the netperf command:

Option	Description
-H	Where to find the server
11.4.17.6	IPoIB IP address
-t <Test Name>	Specify the test to perform. Options are TCP_STREAM, TCP_RR, etc.
-c	Client CPU utilization
-C	Server CPU utilization
--	Separates the global and test-specific parameters
-r 1,1	The request size sent and how many bytes requested back

Note that the run example above produced the following results:

- Client CPU utilization is 5.61 percent of client CPU
- Server CPU utilization is 6.79 percent of server CPU
- Latency is 25.11 microseconds. Latency is calculated as follows:
  0.5*(1 / Transaction rate per sec) * 1,000,000 = one-way average latency in usec.

Step 6. To end the test, shut down the Netperf server.

```
host1$ pkill netserver
```

4 RDS

4.1 Overview

Reliable Datagram Sockets (RDS) is a socket API that provides reliable, in-order datagram delivery between sockets over RC or TCP/IP. RDS is intended for use with Oracle RAC 11g.

For programming details, enter:

```
host1$ man rds
```

4.2 RDS Configuration

The RDS ULP is installed as part of Mellanox OFED for Linux. To load the RDS module upon boot, edit the file `/etc/infiniband/openib.conf` and set "RDS_LOAD=yes".

Note: For the changes to take effect, run: `/etc/init.d/openibd restart`

5 SDP

5.1 Overview

Sockets Direct Protocol (SDP) is an InfiniBand byte-stream transport protocol that provides TCP stream semantics. Capable of utilizing InfiniBand's advanced protocol offload capabilities, SDP can provide lower latency, higher bandwidth, and lower CPU utilization than IPoIB running some sockets-based applications.

SDP can be used by applications and improve their performance transparently (that is, without any recompilation). Since SDP has the same socket semantics as TCP, an existing application is able to run using SDP; the difference is that the application's TCP socket gets replaced with an SDP socket.

It is also possible to configure the driver to automatically translate TCP to SDP based on the source IP, the destination, or the application name. See Section 5.5.

The SDP protocol is composed of a kernel module that implements the SDP as a new address-family/protocol-family, and a library (see Section 5.2) that is used for replacing the TCP address family with SDP according to a policy.

This chapter includes the following sections:

5.2 libsdp.so Library

`libsdp.so` is a dynamically linked library, which is used for transparent integration of applications with SDP. The library is preloaded, and therefore takes precedence over glibc for certain socket calls. Thus, it can transparently replace the TCP socket family with SDP socket calls.

The library also implements a user-level socket switch. Using a configuration file, the system administrator can set up the policy that selects the type of socket to be used. `libsdp.so` also has the option to allow server sockets to listen on both SDP and TCP interfaces. The various configurations with SDP/TCP sockets are explained inside the `/etc/libsdp.conf` file.

5.3 Configuring SDP

To load SDP upon boot, edit the file `/etc/infiniband/openib.conf` and set "SDP_LOAD=yes".

Note: For the changes to take effect, run: `/etc/init.d/openibd restart`

SDP shares the same IP addresses and interface names as IPoIB. See IPoIB configuring in Section 3.2 and Section 3.3.

5.3.1 How to Know SDP Is Working

Since SDP is a transparent TCP replacement, it can sometimes be difficult to know that it is working correctly. The `sdpnetstat` program can be used to verify both that SDP is loaded and is being used:

```
host1$ sdpnetstat -S
```

This command shows all active SDP sockets using the same format as the traditional `netstat` program. Without the '-S' option, it shows all the information that `netstat` does plus SDP data.

Assuming that the SDP kernel module is loaded and is being used, then the output of the command will show an error like the following:

```
host1$ sdpnetstat -S
Proto Recv-Q Send-Q Local Address           Foreign Address
sdp        0      0 193.168.10.144:34216    193.168.10.125:12865
sdp        0 884720 193.168.10.144:42724    193.168.10.:filenet-rmi
```

The example output above shows two active SDP sockets and contains details about the connections.

If the SDP kernel module is not loaded, or it is loaded but is not being used, then the output of the command will be something like the following:

```
host1$ sdpnetstat -S
Proto Recv-Q Send-Q Local Address           Foreign Address
netstat: no support for `AF INET (tcp)' on this system.
```

To verify whether the module is loaded or not, you can use the `lsmod` command:

```
host1$ lsmod | grep sdp
ib_sdp    125020     0
```

The example output above shows that the SDP module is loaded.

If the SDP module *is* loaded and the `sdpnetstat` command did not show SDP sockets, then SDP is not being used by the application.

5.3.2 Monitoring and Troubleshooting Tools

SDP has debug support for both the user space `libsdp.so` library and the `ib_sdp` kernel module.. Both can be useful to understand why a TCP socket was not redirected over SDP and to help find problems in the SDP implementation.

User Space SDP Debug

User-space SDP debug is controlled by options in the `libsdp.conf` file. You can also have a local version and point to it explicitly using the following command:

```
host1$ export LIBSDP_CONFIG_FILE=<path>/libsdp.conf
```

To obtain extensive debug information, you can modify `libsdp.conf` to have the `log` directive produce maximum debug output (provide the `min-level` flag with the value 1).

The **`log`** statement enables the user to specify the debug and error messages that are to be sent and their destination. The syntax of **`log`** is as follows:

`log [destination (stderr | syslog | file <filename>)] [min-level 1-9]`

where options are:

destination	send log messages to the specified destination:
	stderr: forward messages to the STDERR
	syslog: send messages to the syslog service
	file <filename>: write messages to the file /var/log/filename for root. For a regular user, write to /tmp/<filename>.<uid> if filename is not specified as a full path; otherwise, write to <path>/<filename>.<uid>
min-level	verbosity level of the log:
	9: print errors only
	8: print warnings
	7: print connect and listen summary (useful for tracking SDP usage)
	4: print positive match summary (useful for config file debug)
	3: print negative match summary (useful for config file debug)
	2: print function calls and return values
	1: print debug messages

Examples:

To print SDP usage per connect and listern to STDERR, include the following statement:

```
log min-level 7 destination stderr
```

A non-root user can configure `libsdp.so` to record function calls and return values in the file `/tmp/libsdp.log.<pid>` (root log goes to `/var/log/libsdp.log` for this example) by including the following statement in `libsdp.conf`:

```
log min-level 2 destination file libsdp.log
```

To print errors only to syslog, include the following statement:

```
log min-level 9 destination syslog
```

To print maximum output to the file `/tmp/sdp_debug.log.<pid>`, include the following statement:

```
log min-level 1 destination file sdp_debug.log
```

Kernel Space SDP Debug

The SDP kernel module can log detailed trace information if you enable it using the 'debug_level' variable in the sysfs filesystem. The following command performs this:

```
host1$ echo 1 > /sys/module/ib_sdp/debug_level
```

Note: Depending on the operating system distribution on your machine, you may need an extra level—parameters— in the directory structure, so you may need to direct the echo command to `/sys/module/ib_sdp/parameters/debug_level`.

Turning off kernel debug is done by setting the sysfs variable to zero using the following command:

```
host1$ echo 0 > /sys/module/ib_sdp/debug_level
```

To display debug information, use the `dmesg` command:

```
host1$ dmesg
```

5.4 Environment Variables

For the transparent integration with SDP, the following two environment variables are required:

1. LD_PRELOAD – this environment variable is used to preload `libsdp.so` and it should point to the `libsdp.so` library. The variable should be set by the system administrator to `/usr/lib/libsdp.so (or /usr/lib64/libspd.so)`.
2. LIBSDP_CONFIG_FILE – this environment variable is used to configure the policy for replacing TCP sockets with SDP sockets. By default it points to: `/etc/libsdp.conf`.

5.5 Converting Socket-based Applications

You can convert a socket-based application to use SDP instead of TCP in an automatic (also called transparent) mode or in an explicit (also called non-transparent) mode.

Automatic (Transparent) Conversion

The `libsdp.conf` configuration (policy) file is used to control the automatic transparent replacement of TCP sockets with SDP sockets. In this mode, socket streams are converted based upon a destination port, a listening port, or a program name.

Socket control statements in `libsdp.conf` allow the user to specify when `libsdp` should replace AF_INET/SOCK_STREAM sockets with AF_SDP/SOCK_STREAM sockets. Each control statement specifies a matching rule that applies if all its subexpressions must evaluate as true (logical and).

The `use` statement controls which type of sockets to open. The format of a `use` statement is as follows:

```
use <address-family> <role> <program-name|*> <address|*>:<port range|*>
```

where

```
<address-family>
      can be one of
      sdp: for specifying when an SDP should be used
      tcp: for specifying when an SDP socket should not be matched
      both: for specifying when both SDP and AF_INET sockets should be
      used
```

Note that *both* semantics is different for *server* and *client* roles. For *server*, it means that the *server* will be listening on both SDP and TCP sockets. For *client*, the connect function will first attempt to use SDP and will silently fall back to TCP if the SDP connection fails.

<role>

can be one of

server or listen: for defining the listening port address family

client or connect: for defining the connected port address family

<program-name|*>

Defines the program name the rule applies to (not including the path). Wildcards with same semantics as 'ls' are supported (* and ?). So db2* would match on any program with a name starting with db2. t?cp would match on ttcp, etc.

If program-name is not provided (default), the statement matches all programs.

<address|*>

Either the local address to which the server binds, or the remote server address to which the client connects. The syntax for address matching is:

<IPv4 address>[/<prefix_length>]|*

IPv4 address = [0-9]+\.[0-9]+\.[0-9]+\.[0-9]+ each sub number < 255

prefix_length = [0-9]+ and with value <= 32. A prefix_length of 24 matches the subnet mask 255.255.255.0. A prefix_length of 32 requires matching of the exact IP.

<port range>

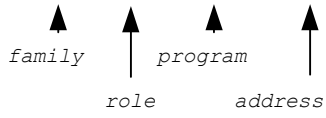
start-port[-end-port] where port numbers are >0 and <65536

Note that rules are evaluated in the order of definition. So the first match wins. If no match is made, `libsdp` will default to `both`.

Examples:

- Use SDP by clients connecting to machines that belongs to subnet 192.168.1.*

```
use sdp connect *  192.168.1.0/24:*
```



- Use SDP by ttcp when it connects to port 5001 of any machine

```
use sdp    listen  ttcp      *:5001
```

- Use TCP for any program with name starting with ttcp* serving ports 22 to 25

```
use tcp    server  ttcp*     *:22-25
```

- Listen on both TCP and SDP by any server that listen on port 8080

```
use both   server  *         *:8080
```

- Connect ssh through SDP and fallback to TCP to hosts on 11.4.8.* port 22

```
use both   connect *         11.4.8.0/24:22
```

Explicit (Non-transparent) Conversion

Use explicit conversion if you need to maintain full control from your application while using SDP. To configure an explicit conversion to use SDP, simply recompile the application replacing PF_INET (or PF_INET) with AF_INET_SDP (or AF_INET_SDP) when calling the `socket()` system call in the source code. The value of AF_INET_SDP is defined in the file `sdp_socket.h` or you can define it inline:

```
#define AF_INET_SDP 27
#define PF_INET_SDP AF_INET_SDP
```

You can compile and execute the following very simple TCP application that has been converted explicitly to SDP:

Compilation:

```
gcc sdp_server.c -o sdp_server
gcc sdp_client.c -o sdp_client
```

Usage:

Server:

```
host1$ sdp_server
```

Client:

```
host1$ sdp_client <server IPoIB addr>
```

Example:

Server:

```
host1$ ./sdp_server
accepted connection from 15.2.2.42:48710
read 2048 bytes
end of test
host1$
```

Client:

```
host2$  ./sdp_client 15.2.2.43
connected to 15.2.2.43:22222
sent 2048 bytes
host2$
```

sdp_client.c Code

```
/*
 *  usage: ./sdp_client <ip_addr>
 */
```

```
#include <stdio.h>
#include <stdlib.h>
#include <stdint.h>
#include <unistd.h>
#include <string.h>

#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>

#define DEF_PORT 22222

#define AF_INET_SDP 27
#define PF_INET_SDP AF_INET_SDP

#define TXBUFSZ 2048
uint8_t tx_buffer[TXBUFSZ];

int
main(int argc, char **argv)
{
    if ( argc < 2) {
        printf("Usage: sdp_client <ip_addr>\n");
        exit(EXIT_FAILURE);
    }

    int sd = socket(PF_INET_SDP, SOCK_STREAM, 0);
    if ( sd < 0) {
        perror("socket() failed");
        exit(EXIT_FAILURE);
    }

    struct sockaddr_in to_addr = {
        .sin_family = AF_INET,
        .sin_port = htons(DEF_PORT),
    };

    int ip_ret = inet_aton(argv[1], &to_addr.sin_addr);
    if ( ip_ret == 0) {
        printf("invalid ip address '%s'\n", argv[1]);
        exit(EXIT_FAILURE);
    }
```

```
    int conn_ret = connect(sd, (struct sockaddr *) &to_addr,
sizeof(to_addr));
    if ( conn_ret < 0) {
        perror("connect() failed");
        exit(EXIT_FAILURE);
    }

    printf("connected to %s:%u\n",
            inet_ntoa(to_addr.sin_addr),
            ntohs(to_addr.sin_port) );


    ssize_t nw = write(sd, tx_buffer, TXBUFSZ);
    if ( nw < 0) {
        perror("write() failed");
        exit(EXIT_FAILURE);
    } else if ( nw == 0) {
        printf("socket was closed by remote host\n");
    }

    printf("sent %zd bytes\n", nw);

    close(sd);

    return 0;
}
```

sdp_server.c Code

```
/*
 * Usage: ./sdp_server
 */

#include <stdio.h>
#include <stdlib.h>
#include <stdint.h>
#include <unistd.h>

#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>
```

```
#include <sys/epoll.h>
#include <errno.h>
#include <assert.h>

#define RXBUFSZ 2048

uint8_t rx_buffer[RXBUFSZ];

#define DEF_PORT 22222

#define AF_INET_SDP 27
#define PF_INET_SDP AF_INET_SDP

int
main(int argc, char **argv)
{

    int sd = socket(PF_INET_SDP, SOCK_STREAM, 0);
    if ( sd < 0) {
        perror("socket() failed");
        exit(EXIT_FAILURE);
    }

    struct sockaddr_in my_addr = {
        .sin_family = AF_INET,
        .sin_port = htons(DEF_PORT),
        .sin_addr.s_addr = INADDR_ANY,
    };



    int retbind = bind(sd, (struct sockaddr *) &my_addr, sizeof(my_addr)
);
    if ( retbind < 0) {
        perror("bind() failed");
        exit(EXIT_FAILURE);
    }

    int retlisten = listen(sd, 5/*backlog*/);
    if ( retlisten < 0) {
        perror("listen() failed");
        exit(EXIT_FAILURE);
    }
```

```
    // accept the client connection
    struct sockaddr_in client_addr;

    socklen_t client_addr_len = sizeof(client_addr);
    int cd = accept(sd, (struct sockaddr *) &client_addr,
&client_addr_len);
    if ( cd < 0) {
        perror("accept() failed");
        exit(EXIT_FAILURE);
    }

    printf("accepted connection from %s:%u\n",
            inet_ntoa(client_addr.sin_addr),
            ntohs(client_addr.sin_port) );

    ssize_t nr = read(cd, rx_buffer, RXBUFSZ);
    if ( nr < 0) {
        perror("read() failed");
        exit(EXIT_FAILURE);
    } else if ( nr == 0) {
        printf("socket was closed by remote host\n");
    }

    printf("read %zd bytes\n", nr);

    printf("end of test\n");

    close(cd);
    close(sd);

    return 0;
}
```

5.6 Testing SDP Performance

This section describes how to verify SDP performance by running the Bandwidth (BW) test and the Latency test. These tests are described in detail at the following URL:

http://www.netperf.org/netperf/training/Netperf.html

To verify SDP performance, perform the following steps:

Step 1. Download Netperf from the following URL:

http://www.netperf.org/netperf/NetperfPage.html

Step 2. Compile Netperf by following the instructions at http://www.netperf.org/netperf/NetperfPage.html.

Step 3. Create `libsdp.conf` (configuration file).

```
host1# cat > $HOME/libsdp.conf << EOF
> match destination *:*
> match listen *:*
> EOF
```

Step 4. Start the Netperf server such that you force SDP to be used instead of TCP.

```
host1# LD_PRELOAD=libsdp.so LIBSDP_CONFIG_FILE=$HOME/libsdp.conf netserver
Starting netserver at port 12865
Starting netserver at hostname 0.0.0.0 port 12865 and family AF_UNSPEC
host1#
```

Step 5. Run the Netperf client such that you force SDP to be used instead of TCP. The default test is the Bandwidth test.

```
host2# LD_PRELOAD=libsdp.so LIBSDP_CONFIG_FILE=$HOME/libsdp.conf netperf \
-H 11.4.17.6 -t TCP_STREAM -c -C -- -m 65536
TCP STREAM TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET to 11.4.17.6
(11.4.17.6) port 0 AF_INET
Recv   Send    Send                          Utilization       Service Demand
Socket Socket  Message  Elapsed              Send     Recv     Send    Recv
Size   Size    Size     Time     Throughput  local    remote   local   remote
bytes  bytes   bytes    secs.    10^6bits/s  % S      % S      us/KB   us/KB

 87380  16384  65536    10.00      5872.60   19.41    17.12    2.166   1.911
```

Note: You must specify the SDP/IPoIB IP address when running the Netperf client.

The following table describes parameters for the netperf command:

Option	Description
-H	Where to find the server
11.4.17.6	SDP/IPoIB IP address
-t <Test Name>	Specify the test to perform. Options are TCP_STREAM, TCP_RR, etc.
-c	Client CPU utilization
-C	Server CPU utilization

Option	Description
--	Separates the global and test-specific parameters
-m	Message size, which is 65536 in the example above

Note that the run example above produced the following results:

- Throughput is 5.872 gigabits per second
- Client CPU utilization is 19.41 percent of client CPU
- Server CPU utilization is 17.12 percent of server CPU

Step 6. Run the Netperf Latency test such that you force SDP to be used instead of TCP.

Run the test once, and stop the server so that it does not repeat the test.

```
host2# LD_PRELOAD=libsdp.so LIBSDP_CONFIG_FILE=$HOME/libsdp.conf netperf \
 -H 11.4.17.6 -t TCP_RR -c -C -- -r1,1
    TCP REQUEST/RESPONSE TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET to 11.4.17.6
    (11.4.17.6) port 0 AF_INET
    Local /Remote
    Socket Size   Request Resp.  Elapsed Trans.   CPU    CPU    S.dem   S.dem
    Send   Recv   Size    Size   Time    Rate     local  remote local   remote
    bytes  bytes  bytes   bytes  secs.   per sec  % S    % S    us/Tr   us/Tr

    16384  87380  1       1      10.00   37572.83  15.72  23.36  33.469  49.729
    16384  87380
```

The following table describes parameters for the netperf command:

Option	Description
-H	Where to find the server
11.4.17.6	SDP/IPoIB IP address
-t <Test Name>	Specify the test to perform. Options are TCP_STREAM, TCP_RR, etc.
-c	Client CPU utilization
-C	Server CPU utilization
--	Separates the global and test-specific parameters
-r 1,1	The request size sent and how many bytes requested back

Note that the run example above produced the following results:

- Client CPU utilization is 15.72 percent of client CPU
- Server CPU utilization is 23.36 percent of server CPU
- Latency is 13.31 microseconds. Latency is calculated as follows:
  0.5*(1 / Transaction rate per sec) * 1,000,000 = one-way average latency in usec.

Step 7. To end the test, shut down the Netperf server.

```
host1# pkill netserver
```

6 SRP

6.1 Overview

As described in Section 1.3.3, the SCSI RDMA Protocol (SRP) is designed to take full advantage of the protocol offload and RDMA features provided by the InfiniBand architecture. SRP allows a large body of SCSI software to be readily used on InfiniBand architecture. The SRP Initiator controls the connection to an SRP Target in order to provide access to remote storage devices across an InfiniBand fabric. The SRP Target resides in an IO unit and provides storage services.

Section 6.2 describes the SRP Initiator included in Mellanox OFED for Linux. This package, however, does *not* include an SRP Target.

6.2 SRP Initiator

This SRP Initiator is based on open source from OpenFabrics (www.openfabrics.org) that implements the SCSI RDMA Protocol-2 (SRP-2). SRP-2 is described in Document # T10/1524-D available from www.t10.org/ftp/t10/drafts/srp2/srp2r00a.pdf.

The SRP Initiator supports

- Basic SCSI Primary Commands -3 (SPC-3)
  (www.t10.org/ftp/t10/drafts/spc3/spc3r21b.pdf)
- Basic SCSI Block Commands -2 (SBC-2)
  (www.t10.org/ftp/t10/drafts/sbc2/sbc2r16.pdf)
- Basic functionality, task management and limited error handling

6.2.1 Loading SRP Initiator

To load the SRP module, either execute the "modprobe ib_srp" command after the OFED driver is up, or change the value of SRP_LOAD in `/etc/infiniband/openib.conf` to "yes".

Note: For the changes to take effect, run: `/etc/init.d/openibd restart`

Note: When loading the ib_srp module, it is possible to set the module parameter srp_sg_tablesize. This is the maximum number of gather/scatter entries per I/O (default: 12).

6.2.2 Manually Establishing an SRP Connection

The following steps describe how to manually load an SRP connection between the Initiator and an SRP Target. Section 6.2.4 explains how to do this automatically.

- Make sure that the `ib_srp` module is loaded, the SRP Initiator is reachable by the SRP Target, and that an SM is running.
- To establish a connection with an SRP Target and create an SRP (SCSI) device for that target under `/dev`, use the following command:

```
echo -n id_ext=[GUID value],ioc_guid=[GUID value],dgid=[port GID value],\
pkey=ffff,service_id=[service[0] value] > \
/sys/class/infiniband_srp/srp-mthca[hca number]-[port number]/add_target
```

See Section 6.2.3 for instructions on how the parameters in this `echo` command may be obtained.

Notes:

- Execution of the above “echo” command may take some time
- The SM must be running while the command executes
- It is possible to include additional parameters in the echo command:
  - > max_cmd_per_lun - Default: 63
  - > max_sect (short for max_sectors) - sets the request size of a command
  - > io_class - Default: 0x100 as in rev 16A of the specification

  (In rev 10 the default was 0xff00)
  - > initiator_ext - Please refer to Section 9 (Multiple Connections...)

- To list the new SCSI devices that have been added by the echo command, you may use either of the following two methods:
  - Execute “fdisk -l”. This command lists all devices; the new devices are included in this listing.
  - Execute “dmesg” or `look at /var/log/messages` to find messages with the names of the new devices.

6.2.3 SRP Tools - ibsrpdm and srp_daemon

To assist in performing the steps in Section 6, the OFED 1.3 distribution provides two utilities, ibsrpdm and srp_daemon, which

- Detect targets on the fabric reachable by the Initiator (for Step 1)
- Output target attributes in a format suitable for use in the above “echo” command (Step 2)

The utilities can be found under `/usr/sbin/`, and are part of the srptools RPM that may be installed using the Mellanox OFED installation. Detailed information regarding the various options for these utilities are provided by their man pages.

Below, several usage scenarios for these utilities are presented.

ibsrpdm

ibsrpdm is using for the following tasks:

1. Detecting reachable targets
   a. To detect all targets reachable by the SRP initiator via the default umad device (/dev/umad0), execute the following command:

      `ibsrpdm`

      This command will output information on each SRP Target detected, in human-readable form.

      Sample output:

```
IO Unit Info:
     port LID:        0103
```

```
    port GID:        fe80000000000000002c90200402bd5
    change ID:       0002
    max controllers: 0x10
controller[  1]
     GUID:      0002c90200402bd4
     vendor ID: 0002c9
     device ID: 005a44
     IO class : 0100
     ID:        LSI Storage Systems SRP Driver 200400a0b81146a1
     service entries: 1
     service[  0]: 200400a0b81146a1 / SRP.T10:200400A0B81146A1
```

b. To detect all the SRP Targets reachable by the SRP Initiator via another umad device, use the following command:

```
ibsrpdm -d <umad device>
```

2. Assistance in creating an SRP connection

a. To generate output suitable for utilization in the "echo" command of Section 6.2.2, add the '-c' option to ibsrpdm:

```
ibsrpdm -c
```

Sample output:

```
id_ext=200400A0B81146A1,ioc_guid=0002c90200402bd4,
dgid=fe80000000000000002c90200402bd5,pkey=ffff,
 service_id=200400a0b81146a1
```

b. To establish a connection with an SRP Target using the output from the '`libsrpdm -c`' example above, execute the following command:

```
echo -n id_ext=200400A0B81146A1,ioc_guid=0002c90200402bd4,
dgid=fe80000000000000002c90200402bd5,pkey=ffff,
service_id=200400a0b81146a1 > /sys/class/infiniband_srp/srp-mthca0-1/
add_target
```

The SRP connection should now be up; the newly created SCSI devices should appear in the listing obtained from the '`fdisk -l`' command.

srp_daemon

The srp_daemon utility is based on ibsrpdm and extends its functionality. In addition to the ibsrpdm functionality described above, srp_daemon can also

- Establish an SRP connection by itself (without the need to issue the "echo" command described in Section 6.2.2)
- Continue running in background, detecting new targets and establishing SRP connections with them (daemon mode)
- Discover reachable SRP Targets given an infiniband HCA name and port, rather than just by /dev/umad<N> where <N> is a digit

- Enable High Availability operation (together with Device-Mapper Multipath)
- Have a configuration file that determines the targets to connect to

1. `srp_daemon` commands equivalent to ibsrpdm:

```
"srp_daemon -a -o"    is equivalent to "ibsrpdm"
"srp_daemon -c -a -o" is equivalent to "ibsrpdm -c"
```

Note: These srp_daemon commands can behave differently than the equivalent ibsrpdm command when /etc/srp_daemon.conf is not empty.

2. `srp_daemon` extensions to `ibsrpdm`

- To discover SRP Targets reachable from the HCA device <InfiniBand HCA name> and the port <port num>, (and to generate output suitable for 'echo',) you may execute:

```
host1# srp_daemon -c -a -o -i <InfiniBand HCA name> -p <port number>
```

Note: To obtain the list of InfiniBand HCA device names, you can either use the `ibstat` tool or run '`ls /sys/class/infiniband`'.

- To both discover the SRP Targets and establish connections with them, just add the -e option to the above command.
- Executing srp_daemon over a port without the -a option will only display the reachable targets via the port and to which the initiator is not connected. If executing with the -e option it is better to omit -a.
- It is recommended to use the -n option. This option adds the initiator_ext to the connecting string. (See Section 6.2.5 for more details).
- srp_daemon has a configuration file that can be set, where the default is /etc/srp_daemon.conf. Use the -f to supply a different configuration file that configures the targets srp_daemon is allowed to connect to. The configuration file can also be used to set values for additional parameters (e.g., max_cmd_per_lun, max_sect).
- A continuous background (daemon) operation, providing an automatic ongoing detection and connection capability. See Section 6.2.4.

6.2.4 Automatic Discovery and Connection to Targets

- Make sure that the ib_srp module is loaded, the SRP Initiator can reach an SRP Target, and that an SM is running.
- To connect to all the existing Targets in the fabric, run "**`srp_daemon -e -o`**". This utility will scan the fabric once, connect to every Target it detects, and then exit.

Note: srp_daemon will follow the configuration it finds in /etc/srp_daemon.conf. Thus, it will ignore a target that is disallowed in the configuration file.

- To connect to all the existing Targets in the fabric and to connect to new targets that will join the fabric, execute srp_daemon -e. This utility continues to execute until it is either killed by the user or encounters connection errors (such as no SM in the fabric).
- To execute SRP daemon as a daemon you may run "**`run_srp_daemon`**" (found under `/usr/sbin/`), providing it with the same options used for running `srp_daemon`.

Note: Make sure only one instance of `run_srp_daemon` runs per port.

- To execute SRP daemon as a daemon on all the ports, run "**`srp_daemon.sh`**" (found under `/usr/sbin/`). `srp_daemon.sh` sends its log to `/var/log/srp_daemon.log`.
- It is possible to configure this script to execute automatically when the InfiniBand driver starts by changing the value of SRPHA_ENABLE in `/etc/infiniband/openib.conf` to "yes". However, this option also enables SRP High Availability that has some more features – see Section 6.2.6).

Note: For the changes in `openib.conf` to take effect, run:
`/etc/init.d/openibd restart`

6.2.5 Multiple Connections from Initiator IB Port to the Target

Some system configurations may need multiple SRP connections from the SRP Initiator to the same SRP Target: to the same Target IB port, or to different IB ports on the same Target HCA.

In case of a single Target IB port, i.e., SRP connections use the same path, the configuration is enabled using a different initiator_ext value for each SRP connection. The initiator_ext value is a 16-hexadecimal-digit value specified in the connection command.

Also in case of two physical connections (i.e., network paths) from a single initiator IB port to two different IB ports on the same Target HCA, there is need for a different initiator_ext value on each path. The conventions is to use the Target port GUID as the initiator_ext value for the relevant path.

If you use srp_daemon with -n flag, it automatically assigns initiator_ext values according to this convention. For example:

```
id_ext=200500A0B81146A1,ioc_guid=0002c90200402bec,\
dgid=fe8000000000000002c90200402bed,pkey=ffff,\
service_id=200500a0b81146a1,initiator_ext=ed2b400002c90200
```

Notes:

1. It is recommended to use the -n flag for all srp_daemon invocations.
2. ibsrpdm does not have a corresponding option.
3. srp_daemon.sh always uses the -n option (whether invoked manually by the user, or automatically at startup by setting SRPHA_ENABLE to yes).

6.2.6 High Availability (HA)

Overview

High Availability works using the Device-Mapper (DM) multipath and the SRP daemon. Each initiator is connected to the same target from several ports/HCAs. The DM multipath is responsible for joining together different paths to the same target and for fail-over between paths when one of them goes offline. Multipath will be executed on newly joined SCSI devices.

Each initiator should execute several instances of the SRP daemon, one for each port. At startup, each SRP daemon detects the SRP Targets in the fabric and sends requests to the ib_srp module to connect to each of them. These SRP daemons also detect targets that subsequently join the fabric, and send the ib_srp module requests to connect to them as well.

Operation

When a path (from port1) to a target fails, the ib_srp module starts an error recovery process. If this process gets to the reset_host stage and there is no path to the target from this port, ib_srp will remove this scsi_host. After the scsi_host is removed, multipath switches to another path to this target (from another port/HCA).

When the failed path recovers, it will be detected by the SRP daemon. The SRP daemon will then request ib_srp to connect to this target. Once the connection is up, there will be a new scsi_host for this target. Multipath will be executed on the devices of this host, returning to the original state (prior to the failed path).

Prerequisites

Installation for RHEL4/5: (Execute once)

- Verify that the standard device-mapper-multipath rpm is installed. If not, install it from the RHEL distribution.

Installation for SLES10: (Execute once)

- Verify that multipath is installed. If not, take it from the installation (you may use ‘`yast`’).
- Update udev: (Execute once - for manual activation of High Availability only)
- Add a file to /etc/udev/rules.d/ (you can call it 91-srp.rules). This file should have one line:

```
ACTION=="add", KERNEL=="sd*[!0-9]", RUN+="/sbin/multipath %M:%m"
```

Note: When SRPHA_ENABLE is set to "yes" (see Automatic Activation of High Availability below), this file is created upon each boot of the driver and is deleted when the driver is unloaded.

Manual Activation of High Availability

Initialization: (Execute after each boot of the driver)

1. Execute modprobe dm-multipath
2. Execute modprobe ib-srp
3. Make sure you have created file /etc/udev/rules.d/91-srp.rules as described above.
4. Execute for each port and each HCA:

```
srp_daemon -c -e -R 300 -i <InfiniBand HCA name> -p <port number>
```

This step can be performed by executing srp_daemon.sh, which sends its log to /var/log/srp_daemon.log.

Now it is possible to access the SRP LUNs on `/dev/mapper/`.

Note: It is possible for regular (non-SRP) LUNs to also be present; the SRP LUNs may be identified by their names. You can configure the `/etc/multipath.conf` file to change multipath behavior.

Note: It is also possible that the SRP LUNs will not appear under `/dev/mapper/`. This can occur if the SRP LUNs are in the black-list of multipath. Edit the ‘blacklist’

section in `/etc/multipath.conf` and make sure the SRP LUNs are not black-listed.

Automatic Activation of High Availability

- Set the value of SRPHA_ENABLE in `/etc/infiniband/openib.conf` to "yes".

  Note: For the changes in `openib.conf` to take effect, run: `/etc/init.d/openibd restart`

- From the next loading of the driver it will be possible to access the SRP LUNs on /dev/mapper/

  Note: It is possible that regular (not SRP) LUNs may also be present; the SRP LUNs may be identified by their name.

- It is possible to see the output of the SRP daemon in /var/log/srp_daemon.log

6.2.7 Shutting Down SRP

SRP can be shutdown by using "rmmod ib_srp", or by stopping the OFED driver ("`/etc/init.d/openibd stop`"), or as a by-product of a complete system shutdown.

Prior to shutting down SRP, remove all references to it. The actions you need to take depend on the way SRP was loaded. There are three cases:

1. Without High Availability

   When working without High Availability, you should unmount the SRP partitions that were mounted prior to shutting down SRP.
2. After Manual Activation of High Availability

If you manually activated SRP High Availability, perform the following steps:

   a. Unmount all SRP partitions that were mounted.

   b. Kill the SRP daemon instances.

   c. Make sure there are no multipath instances running. If there are multiple instances, wait for them to end or kill them.

   d. Run: `multipath -F`

5. After Automatic Activation of High Availability

   If SRP High Availability was automatically activated, SRP shutdown must be part of the driver shutdown ("/etc/init.d/openibd stop") which performs Steps 2-4 of case b above. However, you still have to unmount all SRP partitions that were mounted before driver shutdown.

7 MPI

7.1 Overview

Mellanox OFED for Linux includes the following MPI implementations over InfiniBand:

- Open MPI – an open source MPI-2 implementation by the Open MPI Project
- OSU MVAPICH – an MPI-1 implementation by Ohio State University

These MPI implementations, along with MPI benchmark tests such as OSU BW/LAT, Intel MPI Benchmark, and Presta, are installed on your machine as part of the Mellanox OFED for Linux installation. Table 5 lists some useful MPI links.

Table 5 - Useful MPI Links

MPI Standard	http://www-unix.mcs.anl.gov/mpi
Open MPI	http://www.open-mpi.org
MVAPICH MPI	http://nowlab.cse.ohio-state.edu/projects/mpi-iba/
MPI Forum	http://www.mpi-forum.org

This chapter includes the following sections:

7.2 Prerequisites for Running MPI

For launching multiple MPI processes on multiple remote machines, the MPI standard provides a launcher program that requires automatic login (i.e., password-less) onto the remote machines. SSH (Secure Shell) is both a computer program and a network protocol that can be used for logging and running commands on remote computers and/or servers.

7.2.1 SSH Configuration

The following steps describe how to configure password-less access over SSH:

Step 1. Generate an ssh key on the initiator machine (host1).

```
host1$ ssh-keygen -t rsa
```

```
Generating public/private rsa key pair.
Enter file in which to save the key (/home/<username>/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/<username>/.ssh/id_rsa.
Your public key has been saved in /home/<username>/.ssh/id_rsa.pub.
The key fingerprint is:
38:1b:29:df:4f:08:00:4a:0e:50:0f:05:44:e7:9f:05 <username>@host1
```

Step 2. Check that the public and private keys have been generated.

```
host1$ cd /home/<username>/.ssh/
host1$ ls
host1$ ls -la
total 40
drwx------  2 root root 4096 Mar  5 04:57 .
drwxr-x--- 13 root root 4096 Mar  4 18:27 ..
-rw-------  1 root root 1675 Mar  5 04:57 id_rsa
-rw-r--r--  1 root root  404 Mar  5 04:57 id_rsa.pub
```

Step 3. Check the public key.

```
host1$ cat id_rsa.pub
ssh-rsa
AAAAB3NzaC1yc2EAAAABIwAAAQEA1zVY8VBHQh9okZN7OA1ibUQ74RXm4zHeczyVxpYHaDPyDmq
ezbYMKrCIVzd10bH+ZkC0rpLYviU0oUHd3fvNTfMs0gcGg08PysUf+12FyYjira2P1xyg6mkHLG
GqVutfEMmABZ3wNCUg6J2X3G/uiuSWXeubZmbXcMrP/
w4IWByfH8ajwo6A5WioNbFZElbYeeNfPZf4UNcgMOAMWp64sL58tkt32F+RGmyLXQWZL27Synsn
6dHpxMqBorXNC0ZBe4kTnUqm63nQ2z1qVMdL9FrCma1xIOu9+SQJAjwONevaMzFKEHe7YHg6YrN
fXunfdbEurzB524TpPcrodZlfCQ== <username>@host1
```

Step 4. Now you need to add the public key to the `authorized_keys2` file on the *target* machine.

```
host1$ cat id_rsa.pub | xargs ssh host2 \
 "echo  >>/home/<username>/.ssh/authorized_keys2"
<username>@host2's password:                // Enter password
host1$
```

For a local machine, simply add the key to `authorized_keys2`.

```
host1$ cat id_rsa.pub >> authorized_keys2
```

Step 5. Test.

```
host1$ ssh  host2  uname
Linux
```

7.3 MPI Selector - Which MPI Runs

Mellanox OFED contains a simple mechanism for system administrators and end-users to select which MPI implementation they want to use. The MPI selector functionality is not specific to any MPI implementation; it can be used with any implementation that provides shell startup files that

correctly set the environment for that MPI. The Mellanox OFED installer will automatically add MPI selector support for each MPI that it installs. Additional MPI's not known by the Mellanox OFED installer can be listed in the MPI selector; see the mpi-selector(1) man page for details.

Note that MPI selector only affects the default MPI environment for *future* shells. Specifically, if you use MPI selector to select MPI implementation ABC, this default selection will not take effect until you start a new shell (e.g., logout and login again). Other packages (such as environment modules) provide functionality that allows changing your environment to point to a new MPI implementation in the current shell. The MPI selector was not meant to duplicate or replace that functionality.

The MPI selector functionality can be invoked in one of two ways:

1. The mpi-selector-menu command.

   This command is a simple, menu-based program that allows the selection of the system-wide MPI (usually only settable by root) and a per-user MPI selection. It also shows what the current selections are. This command is recommended for all users.
2. The mpi-selector command.

   This command is a CLI-equivalent of the mpi-selector-menu, allowing for the same functionality as mpi-selector-menu but without the interactive menus and prompts. It is suitable for scripting.

7.4 Compiling MPI Applications

Note: A valid Fortran compiler must be present in order to build the MVAPICH MPI stack and tests.

The following compilers are supported by Mellanox OFED's MVAPICH and Open MPI packages: Gcc, Intel and PGI. The install script prompts the user to choose the compiler with which to install the MVAPICH and Open MPI RPMs. Note that more than one compiler can be selected simultaneously, if desired.

Compiling MVAPICH Applications

Please refer to http://mvapich.cse.ohio-state.edu/support/mvapich_user_guide.html.

To review the default configuration of the installation, check the default configuration file:

```
/usr/mpi/<compiler>/mvapich-<mvapich-ver>/etc/mvapich.conf
```

Compiling Open MPI Applications

Please refer to http://www.open-mpi.org/faq/?category=mpi-apps.

7.5 OSU MVAPICH Performance

7.5.1 Requirements

- At least two nodes. Example: host1, host2
- Machine file: Includes the list of machines. Example:

```
host1$ cat /home/<username>/cluster
host1
```

```
host2
host1$
```

7.5.2 Bandwidth Test Performance

To run the OSU Bandwidth test, enter:

```
host1$ /usr/mpi/gcc/mvapich-<mvapich-ver>/bin/mpirun_rsh -np 2 \
-hostfile /home/<username>/cluster \
/usr/mpi/gcc/mvapich-<mvapich-ver>/tests/osu_benchmarks-<osu-ver>/osu_bw
# OSU MPI Bandwidth Test v3.0
# Size        Bandwidth (MB/s)
1                          4.62
2                          8.91
4                         17.70
8                         32.59
16                        60.13
32                       113.21
64                       194.22
128                      293.20
256                      549.43
512                      883.23
1024                    1096.65
2048                    1165.60
4096                    1233.91
8192                    1230.90
16384                   1308.92
32768                   1414.75
65536                   1465.28
131072                  1500.36
262144                  1515.26
524288                  1525.20
1048576                 1527.63
2097152                 1530.48
4194304                 1537.50
```

7.5.3 Latency Test Performance

To run the OSU Latency test, enter:

```
host1$ /usr/mpi/gcc/mvapich-<mvapich-ver>/bin/mpirun_rsh -np 2 \
-hostfile /home/<username>/cluster \
/usr/mpi/gcc/mvapich-<mvapich-ver>/tests/osu_benchmarks-<osu-ver>/osu_latency
# OSU MPI Latency Test v3.0
# Size            Latency (us)
0                         1.20
1                         1.21
```

```
2                         1.21
4                         1.21
8                         1.23
16                        1.24
32                        1.33
64                        1.49
128                       2.66
256                       3.08
512                       3.61
1024                      4.82
2048                      6.09
4096                      8.62
8192                     13.59
16384                    18.12
32768                    28.81
65536                    50.38
131072                   93.70
262144                  178.77
524288                  349.31
1048576                 689.25
2097152                1371.04
4194304                2739.16
```

7.5.4 Intel MPI Benchmark

To run the Intel MPI Benchmark test, enter:

```
host1$ /usr/mpi/gcc/mvapich-<mvapich-ver>/bin/mpirun_rsh -np 2 \
-hostfile /home/<username>/cluster \
/usr/mpi/gcc/mvapich-<mvapich-ver>/tests/IMB-<IMB-ver>/IMB-MPI1
#---------------------------------------------------
#    Intel (R) MPI Benchmark Suite V3.0, MPI-1 part
#---------------------------------------------------
# Date                  : Sun Mar  2 19:56:42 2008
# Machine               : x86_64
# System                : Linux
# Release               : 2.6.16.21-0.8-smp
# Version               : #1 SMP Mon Jul 3 18:25:39 UTC 2006
# MPI Version           : 1.2
# MPI Thread Environment: MPI_THREAD_FUNNELED


#
# Minimum message length in bytes:   0
# Maximum message length in bytes:   4194304
#
```

```
# MPI_Datatype                   :   MPI_BYTE
# MPI_Datatype for reductions    :   MPI_FLOAT
# MPI_Op                         :   MPI_SUM
#
#

# List of Benchmarks to run:

# PingPong
# PingPing
# Sendrecv
# Exchange
# Allreduce
# Reduce
# Reduce_scatter
# Allgather
# Allgatherv
# Alltoall
# Alltoallv
# Bcast
# Barrier

#----------------------------------------------------
# Benchmarking PingPong
# #processes = 2
#----------------------------------------------------
       #bytes #repetitions      t[usec]   Mbytes/sec
            0         1000         1.25         0.00
            1         1000         1.24         0.77
            2         1000         1.25         1.52
            4         1000         1.23         3.09
            8         1000         1.26         6.07
           16         1000         1.29        11.83
           32         1000         1.36        22.51
           64         1000         1.52        40.25
          128         1000         2.67        45.74
          256         1000         3.03        80.48
          512         1000         3.64       134.22
         1024         1000         4.89       199.69
         2048         1000         6.30       309.85
         4096         1000         8.91       438.24
         8192         1000        14.07       555.20
        16384         1000        18.85       828.93
```

```
     32768         1000        30.47      1025.75
     65536          640        53.67      1164.57
    131072          320        99.78      1252.80
    262144          160       191.80      1303.44
    524288           80       373.92      1337.19
   1048576           40       742.31      1347.14
   2097152           20      1475.20      1355.75
   4194304           10      2956.95      1352.75

#-- OUTPUT TRUNCATED
```

7.6 Open MPI Performance

7.6.1 Requirements

- At least two nodes. Example: host1, host2
- Machine file: Includes the list of machines. Example:

```
host1$ cat /home/<username>/cluster
host1
host2
host1$
```

7.6.2 Bandwidth Test Performance

To run the OSU Bandwidth test, enter:

```
host1$ /usr/mpi/gcc/openmpi-<ompi-ver>/bin/mpirun -np 2 \
--mca mpi_leave_pinned 1 -hostfile /home/<username>/cluster \
/usr/mpi/gcc/openmpi-<ompi-ver>/tests/osu_benchmarks-<osu-ver>/osu_bw
# OSU MPI Bandwidth Test v3.0
# Size        Bandwidth (MB/s)
1                         1.12
2                         2.24
4                         4.43
8                         8.96
16                       17.38
32                       34.69
64                       69.31
128                     121.29
256                     212.70
512                     326.50
1024                    461.78
2048                    597.85
4096                    543.06
8192                    829.64
16384                  1137.22
```

```
32768                  1386.08
65536                  1520.89
131072                 1622.73
262144                 1659.33
524288                 1679.36
1048576                1675.35
2097152                1668.89
4194304                1671.78
```

7.6.3 Latency Test Performance

To run the OSU Latency test, enter:

```
host1$ /usr/mpi/gcc/openmpi-<ompi-ver>/bin/mpirun -np 2 \
--mca mpi_leave_pinned 1 -hostfile /home/<username>/cluster \
/usr/mpi/gcc/openmpi-<ompi-ver>/tests/osu_benchmarks-<osu-ver>/osu_latency
# OSU MPI Latency Test v3.0
# Size            Latency (us)
0                         1.23
1                         1.37
2                         1.55
4                         1.54
8                         1.55
16                        1.58
32                        1.59
64                        1.59
128                       1.78
256                       2.05
512                       2.69
1024                      3.75
2048                      6.14
4096                     10.07
8192                     12.77
16384                    18.36
32768                    30.52
65536                    48.92
131072                   93.18
262144                  171.92
524288                  341.08
1048576                 737.97
2097152                1729.27
4194304                4226.58
```

7.6.4 Intel MPI Benchmark

To run the Intel MPI Benchmark test, enter:

```
host1$ /usr/mpi/gcc/openmpi-<ompi-ver>/bin/mpirun -np 2 \
--mca mpi_leave_pinned 1 -hostfile /home/<username>/cluster \
/usr/mpi/gcc/openmpi-<ompi-ver>/tests/IMB-<IMB-ver>/IMB-MPI1
#---------------------------------------------------
#    Intel (R) MPI Benchmark Suite V3.0, MPI-1 part
#---------------------------------------------------
# Date                  : Mon Mar 10 12:57:18 2008
# Machine               : x86_64
# System                : Linux
# Release               : 2.6.16.21-0.8-smp
# Version               : #1 SMP Mon Jul 3 18:25:39 UTC 2006
# MPI Version           : 2.0
# MPI Thread Environment: MPI_THREAD_SINGLE

# Minimum message length in bytes:   0
# Maximum message length in bytes:   4194304
#
# MPI_Datatype                   :   MPI_BYTE
# MPI_Datatype for reductions    :   MPI_FLOAT
# MPI_Op                         :   MPI_SUM
#

# List of Benchmarks to run:

# PingPong
# PingPing
# Sendrecv
# Exchange
# Allreduce
# Reduce
# Reduce_scatter
# Allgather
# Allgatherv
# Alltoall
# Alltoallv
# Bcast
# Barrier

#---------------------------------------------------
# Benchmarking PingPong
# #processes = 2
#---------------------------------------------------
       #bytes #repetitions      t[usec]   Mbytes/sec
            0         1000         1.47         0.00
            1         1000         1.57         0.61
            2         1000         1.56         1.22
```

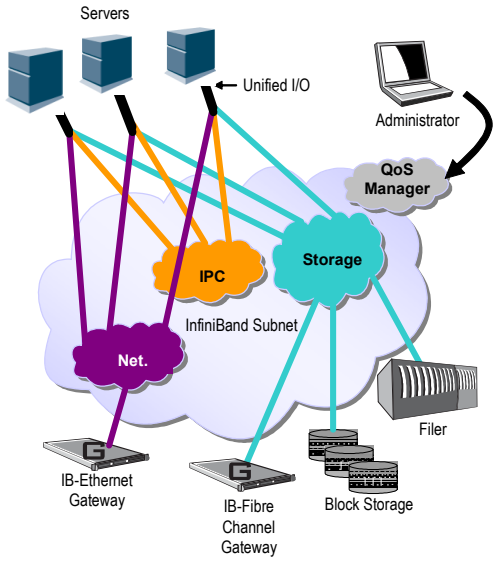
```
             4         1000         1.53         2.49
             8         1000         1.55         4.92
            16         1000         1.60         9.52
            32         1000         1.62        18.86
            64         1000         1.61        37.90
           128         1000         1.80        67.65
           256         1000         2.05       119.26
           512         1000         2.67       183.08
          1024         1000         3.74       260.97
          2048         1000         6.15       317.84
          4096         1000        10.15       384.74
          8192         1000        12.75       612.84
         16384         1000        18.47       845.85
         32768         1000        30.84      1013.28
         65536          640        48.88      1278.77
        131072          320        86.36      1447.43
        262144          160       163.91      1525.26
        524288           80       335.82      1488.90
       1048576           40       726.25      1376.94
       2097152           20      1786.35      1119.60
       4194304           10      4253.59       940.38

#-- OUTPUT TRUNCATED
```

8 Quality of Service

8.1 Overview

Quality of Service (QoS) requirements stem from the realization of I/O consolidation over an IB network. As multiple applications and ULPs share the same fabric, a means is needed to control their use of network resources.

Figure 2: I/O Consolidation Over InfiniBand



QoS over Mellanox OFED for Linux is discussed in Chapter 9, "OpenSM – Subnet Manager".

The basic need is to differentiate the service levels provided to different traffic flows, such that a policy can be enforced and can control each flow utilization of fabric resources.

The InfiniBand Architecture Specification defines several hardware features and management interfaces for supporting QoS:

- Up to 15 Virtual Lanes (VL) carry traffic in a non-blocking manner
- Arbitration between traffic of different VLs is performed by a two-priority-level weighted round robin arbiter. The arbiter is programmable with a sequence of (VL, weight) pairs and a maximal number of high priority credits to be processed before low priority is served
- Packets carry class of service marking in the range 0 to 15 in their header SL field
- Each switch can map the incoming packet by its SL to a particular output VL, based on a programmable table VL=SL-to-VL-MAP(in-port, out-port, SL)
- The Subnet Administrator controls the parameters of each communication flow by providing them as a response to Path Record (PR) or MultiPathRecord (MPR) queries

DiffServ architecture (IETF RFC 2474 & 2475) is widely used in highly dynamic fabrics. The following subsections provide the functional definition of the various software elements that enable a DiffServ-like architecture over the Mellanox OFED software stack.

8.2 QoS Architecture

QoS functionality is split between the SM/SA, CMA and the various ULPs. We take the “chronology approach” to describe how the overall system works.

1. The network manager (human) provides a set of rules (policy) that define how the network is being configured and how its resources are split to different QoS-Levels. The policy also define how to decide which QoS-Level each application or ULP or service use.
2. The SM analyzes the provided policy to see if it is realizable and performs the necessary fabric setup. Part of this policy defines the default QoS-Level of each partition. The SA is enhanced to match the requested Source, Destination, QoS-Class, Service-ID, PKey against the policy, so clients (ULPs, programs) can obtain a policy enforced QoS. The SM may also set up partitions with appropriate IPoIB broadcast group. This broadcast group carries its QoS attributes: SL, MTU, RATE, and Packet Lifetime.
3. IPoIB is being setup. IPoIB uses the SL, MTU, RATE and Packet Lifetime available on the multicast group which forms the broadcast group of this partition.
4. MPI which provides non IB based connection management should be configured to run using hard coded SLs. It uses these SLs for every QP being opened.
5. ULPs that use CM interface (like SRP) have their own pre-assigned Service-ID and use it while obtaining PathRecord/MultiPathRecord (PR/MPR) for establishing connections. The SA receiving the PR/MPR matches it against the policy and returns the appropriate PR/MPR including SL, MTU, RATE and Lifetime.
6. ULPs and programs (e.g. SDP) use CMA to establish RC connection provide the CMA the target IP and port number. ULPs might also provide QoS-Class. The CMA then creates Service-ID for the ULP and passes this ID and optional QoS-Class in the PR/MPR request. The resulting PR/MPR is used for configuring the connection QP.

PathRecord and MultiPathRecord Enhancement for QoS:

As mentioned above, the PathRecord and MultiPathRecord attributes are enhanced to carry the Service-ID which is a 64bit value. A new field QoS-Class is also provided.

A new capability bit describes the SM QoS support in the SA class port info. This approach provides an easy migration path for existing access layer and ULPs by not introducing new set of PR/MPR attributes.

8.3 Supported Policy

The QoS policy, which is specified in a stand-alone file, is divided into the following four subsections:

I. Port Group

A set of CAs, Routers or Switches that share the same settings. A port group might be a partition defined by the partition manager policy, list of GUIDs, or list of port names based on NodeDescription.

II. Fabric Setup

Defines how the SL2VL and VLArb tables should be setup.

Note: In OFED 1.3 this part of the policy is ignored. SL2VL and VLArb tables should be configured in the OpenSM options file (opensm.opts).

III. QoS-Levels Definition

This section defines the possible sets of parameters for QoS that a client might be mapped to. Each set holds SL and optionally: Max MTU, Max Rate, Packet Lifetime and Path Bits.

Note: Path Bits are not implemented in OFED 1.3.

IV. Matching Rules

A list of rules that match an incoming PR/MPR request to a QoS-Level. The rules are processed in order such as the first match is applied. Each rule is built out of a set of match expressions which should all match for the rule to apply. The matching expressions are defined for the following fields:

- SRC and DST to lists of port groups
- Service-ID to a list of Service-ID values or ranges
- QoS-Class to a list of QoS-Class values or ranges

8.4 CMA features

The CMA interface supports Service-ID through the notion of port space as a prefix to the port number, which is part of the sockaddr provided to rdma_resolve_add(). The CMA also allows the ULP (like SDP) to propagate a request for a specific QoS-Class. The CMA uses the provided QoS-Class and Service-ID in the sent PR/MPR.

8.5 IPoIB

IPoIB queries the SA for its broadcast group information and uses the SL, MTU, RATE and Packet Lifetime available on the multicast group which forms this broadcast group.

8.6 SDP

SDP uses CMA for building its connections. The Service-ID for SDP is 0x000000000001PPPP, where PPPP are 4 hexadecimal digits holding the remote TCP/IP Port Number to connect to.

8.7 RDS

RDS uses CMA and thus it is very close to SDP. The Service-ID for RDS is 0x000000000106PPPP, where PPPP are 4 hexadecimal digits holding the TCP/IP Port Number that the protocol connects to.

The default port number for RDS is 0x48CA, which makes a default Service-ID 0x00000000010648CA.

8.8 SRP

The current SRP implementation uses its own CM callbacks (not CMA). So SRP fills in the Service-ID in the PR/MPR by itself and use that information in setting up the QP.

SRP Service-ID is defined by the SRP target I/O Controller (it also complies with IBTA Service-ID rules). The Service-ID is reported by the I/O Controller in the ServiceEntries DMA attribute and should be used in the PR/MPR if the SA reports its ability to handle QoS PR/MPRs.

8.9 OpenSM Features

The QoS related functionality that is provided by OpenSM—the Subnet Manager described in Chapter 9—can be split into two main parts:

I. Fabric Setup

During fabric initialization, the Subnet Manager parses the policy and apply its settings to the discovered fabric elements.

II. PR/MPR Query Handling

OpenSM enforces the provided policy on client request. The overall flow for such requests is: first the request is matched against the defined match rules such that the target QoS-Level definition is found. Given the QoS-Level a path(s) search is performed with the given restrictions imposed by that level.

Note: QoS in OpenSM is described in detail in Chapter 9.

9 OpenSM – Subnet Manager

9.1 Overview

OpenSM is an InfiniBand compliant Subnet Manager (SM). It is provided as a fixed flow executable called *opensm*, accompanied by a testing application called *osmtest*. OpenSM implements an InfiniBand compliant SM according to the InfiniBand Architecture Specification chapters: Management Model (13), Subnet Management (14), and Subnet Administration (15).

9.2 opensm Description

opensm is an InfiniBand compliant Subnet Manager and Subnet Administrator that runs on top of the Mellanox OFED stack. **opensm** performs the InfiniBand specification required task for initializing InfiniBand hardware. One SM must be running for each InfiniBand subnet.

opensm also provides an experimental version of a performance manager.

opensm attaches to a specific IB port on the local machine and configures only the fabric connected to it. (If the local machine has other IB ports, **opensm** will ignore the fabrics connected to those other ports). If no port is specified, **opensm** will select the first "best" available port. **opensm** can also present the available ports and prompt for a port number to attach to.

9.2.1 Syntax

```
opensm [OPTIONS]
```

where OPTIONS are:

```
-c, --cache-options
                Write out a list of all tunable OpenSM parameters, including
                their current values from the command line as well as
                defaults for    others,    into    the   file OSM_CACHE_DIR/
                opensm.opts (OSM_CACHE_DIR defaults to
                /var/cache/opensm if the corresponding environment variable
                is not set). The options file is then used for subsequent
                OpenSM invocations but any command line options take prece-
                dence.


-g, --guid      This  option  specifies  the  local  port  GUID value with
                which OpenSM should bind.  OpenSM may be bound to 1 port  at
                a  time. If the GUID  given  is  0,  OpenSM displays a list
                of possible port GUIDs and waits for user input.  Without -g,
                OpenSM tries to use the default port.


-l, --lmc       This  option  specifies  the  subnet's LMC value.  The number
                of LIDs assigned to each port is 2^LMC.  The LMC value must
                be in the  range  0-7.   LMC  values  > 0 allow multiple
                paths between ports.  LMC values > 0 should only be used if
                the subnet  topology  actually provides multiple paths
```

between ports, i.e. multiple interconnects between switches. Without -l, OpenSM defaults to LMC = 0, which allows one path between any two ports.

-p, --priority This option specifies the SMÂ´s PRIORITY. This will effect the handover cases, where master is chosen by priority and GUID. Range is 0 (default and lowest priority) to 15 (highest).

-smkey This option specifies the SMÂ´s SM_Key (64 bits). This will affect SM authentication.

-r, --reassign_lids

This option causes OpenSM to reassign LIDs to all end nodes. Specifying -r on a running subnet may disrupt subnet traffic. Without -r, OpenSM attempts to preserve existing LID assignments resolving multiple use of same LID.

-R, --routing_engine

This option chooses routing engine instead of Min Hop algorithm (default). Supported engines: updn, file, ftree, lash, dor

-z, --connect_roots

This option enforces a routing engine (currently up/down only) to make connectivity between root switches and in this way to be fully IBA complaint. In many cases this can violate "pure" deadlock free algorithm, so use it carefully.

-M, --lid_matrix_file

This option specifies the name of the lid matrix dump file from where switch lid matrices (min hops tables will be loaded.

-U, --ucast_file This option specifies the name of the unicast dump file from where switch forwarding tables will be loaded.

-S, --sadb_file This option specifies the name of the SA DB dump file from where SA database will be loaded.

-a, --root_guid_file

Set the root nodes for the Up/Down or Fat-Tree routing algorithm to the guids provided in the given file (one to a line).

-u, --cn_guid_file

Set the compute nodes for the Fat-Tree routing algorithm to the guids provided in the given file (one to a line).

-o, --once This option causes OpenSM to configure the subnet once, then exit. Ports remain in the ACTIVE state.

-s, --sweep This option specifies the number of seconds between subnet sweeps. Specifying -s 0 disables sweeping. Without -s, OpenSM defaults to a sweep interval of 10 seconds.

-t, --timeout This option specifies the time in milliseconds used for transaction timeouts. Specifying -t 0 disables timeouts. Without -t, OpenSM defaults to a timeout value of 200 milliseconds.

-maxsmps This option specifies the number of VL15 SMP MADs allowed on the wire at any one time. Specifying -maxsmps 0 allows unlimited outstanding SMPs. Without -maxsmps, OpenSM defaults to a maximum of 4 outstanding SMPs.

-console [off | local | socket | loopback]

This option brings up the OpenSM console (default off). Note that the socket and loopback options will only be available if OpenSM was built with --enable-console-socket.

-console-port <port>

Specify an alternate telnet port for the socket console (default 10000). Note that this option only appears if OpenSM was built with --enable-console-socket.

-i, -ignore-guids <equalize-ignore-guids-file>

This option provides the means to define a set of ports (by guid) that will be ignored by the link load equalization algorithm.

-x, --honor_guid2lid

This option forces OpenSM to honor the guid2lid file, when it comes out of Standby state, if such file exists under OSM_CACHE_DIR, and is valid. By default, this is FALSE.

-f, --log_file This option defines the log to be the given file. By default, the log goes to /var/log/opensm.log. For the log to go to standard output use -f stdout.

-L, --log_limit <size in MB>

This option defines maximal log file size in MB. When specified the log file will be truncated upon reaching this limit.

-e, --erase_log_file

This option will cause deletion of the log file (if it previously exists). By default, the log file is accumulative.

-P, --Pconfig
This option defines the optional partition configuration file. The default name is Â´/etc/ofa/opensm-partitions.conf.

-Q, --qos
This option enables QoS setup. It is disabled by default.

-N, --no_part_enforce
This option disables partition enforcement on switch external ports.

-y, --stay_on_fatal
This option will cause SM not to exit on fatal initialization issues: if SM discovers duplicated guids or a 12x link with lane reversal badly configured. By default, the SM will exit on these errors.

-B, --daemon
Run in daemon mode - OpenSM will run in the background.

-I, --inactive
Start SM in inactive rather than init SM state. This option can be used in conjunction with the perfmgr so as to run a standalone performance manager without SM/SA. However, this is NOT currently implemented in the performance manager.

-perfmgr
Enable the perfmgr. Only takes effect if --enable-perfmgr was specified at configure time.

-perfmgr_sweep_time_s <seconds>
Specify the sweep time for the performance manager in seconds (default is 180 seconds). Only takes effect if --enable-perfmgr was specified at configure time.

-v, --verbose
This option increases the log verbosity level. The -v option may be specified multiple times to further increase the verbosity level. See the -D option for more information about log verbosity.

-V
This option sets the maximum verbosity level and forces log flushing. The -V option is equivalent to '-D 0xFF -d 2'. See the -D option for more information about log verbosity.

-D
This option sets the log verbosity level. A flags field must follow the -D option. A bit set/clear in the flags enables/disables a specific log level as follows:

BIT LOG LEVEL ENABLED
---- -----------------

```
                    0x01   ERROR (error messages)
                    0x02   INFO (basic messages, low volume)
                    0x04   VERBOSE (interesting stuff, moderate volume)
                    0x08   DEBUG (diagnostic, high volume)
                    0x10   FUNCS (function entry/exit, very high volume)
                    0x20   FRAMES (dumps all SMP and GMP frames)
                    0x40   ROUTING (dump FDB routing information)
                    0x80   currently unused

                    Without  -D, OpenSM defaults to ERROR + INFO (0x3). Specify-
                    ing '-D 0' disables all messages.  Specifying '-D 0xFF'
                    enables all messages (see -V). High verbosity levels may
                    require increasing the transaction timeout with the -t
                    option.

-d, --debug         This option specifies a debug option.   These  options  are
                    not normally  needed.   The  number  following  -d selects
                    the debug option to enable as follows:

                    OPT   Description
                    ---   -----------------
                    -d0   Ignore other SM nodes
                    -d1   Force single threaded dispatching
                    -d2   Force log flushing after each log message
                    -d3   Disable multicast support

-h, --help          Display this usage info then exit

-?                  Display this usage info then exit
```

9.2.2 Environment Variables

The following environment variables control `opensm` behavior:

- OSM_TMP_DIR

  Controls the directory in which the temporary files generated by opensm are created. These files are: `opensm-subnet.lst`, `opensm.fdbs`, and `opensm.mcfdbs`. By default, this directory is `/var/log`.

- OSM_CACHE_DIR

  `opensm` stores certain data to the disk such that subsequent runs are consistent. The default directory used is `/var/cache/opensm`. The following files are included in it:

  - `guid2lid` – stores the LID range assigned to each GUID
  - `opensm.opts` – an optional file that holds a complete set of `opensm` configuration options

9.2.3 Signaling

When opensm receives a HUP signal, it starts a new heavy sweep as if a trap was received or a topology change was found.

Also, SIGUSR1 can be used to trigger a reopen of `/var/log/opensm.log` for logrotate purposes.

9.2.4 Running opensm

The defaults of **opensm** were designed to meet the common case usage on clusters with up to a few hundred nodes. Thus, in this default mode, **opensm** will scan the IB fabric, initialize it, and sweep occasionally for changes. To run **opensm** in the default mode, simply enter:

```
host1# opensm
```

Note that **opensm** needs to be run on at least one machine in an IB subnet.

By default, an **opensm** run is logged to two files: `/var/log/messages` and `/var/log/opensm.log`. The first file, `message`, registers only general major events; the second file, `opensm.log`, includes details of reported errors. All errors reported in `opensm.log` should be treated as indicators of IB fabric health. Both log files should include the message “SUBNET UP” if opensm was able to setup the subnet correctly.

Note: If a fatal, non-recoverable error occurs, **opensm** exits.

9.2.4.1 Running OpenSM As Daemon

OpenSM can also run as daemon. To run OpenSM in this mode, enter:

```
host1# /etc/init.d/opensmd start
```

9.3 osmtest Description

osmtest is a test program for validating the InfiniBand Subnet Manager and Subnet Administrator. **osmtest** provides a test suite for **opensm**. It can create an inventory file of all available nodes, ports, and PathRecords, including all their fields. It can also verify the existing inventory with all the object fields, and matches it to a pre-saved one. See Section 9.3.2.

osmtest has the following test flows:

- Multicast Compliancy test
- Event Forwarding test
- Service Record registration test
- RMPP stress test
- Small SA Queries stress test

9.3.1 Syntax

```
osmtest [OPTIONS]
```

where OPTIONS are:

```
-f, --flow      This option directs osmtest to run a specific flow:
```

```
                    Flow  Description:
                    c = create an inventory file with all nodes, ports and paths
                    a = run all validation tests (expecting an input inventory)
                    v = only validate the given inventory file
                    s = run service registration, deregistration, and lease test
                    e = run event forwarding test
                    f = flood the SA with queries according to the stress mode
                    m = multicast flow
                    q = QoS info: dump VLArb and SLtoVL tables
                    t = run trap 64/65 flow (this flow requires running of exter-
                    nal tool)
                    Default = all flows except QoS

-w, --wait          This option specifies the wait time for trap 64/65 in sec-
                    onds. It is used only when running -f t - the trap 64/65 flow
                    Default = 10 sec
-d, --debug         This  option  specifies  a  debug option.  These options are
                    not normally needed.  The number  following  -d  selects  the
                    debug option to enable as follows:
                    OPT   Description
                    ---   -----------------
                    -d0   Ignore other SM nodes
                    -d1   Force single threaded dispatching
                    -d2   Force log flushing after each log message
                    -d3   Disable multicast support

-m, --max_lid       This  option specifies the maximal LID number to be searched
                    for during inventory file build (Default = 100)

-g, --guid          This option specifies the  local  port  GUID  value  with
                    which OpenSM  should  bind.   OpenSM may be bound to 1 port
                    at a time. If GUID given is 0, OpenSM displays  a  list  of
                    possible  port GUIDs  and waits for user input.  Without -g,
                    OpenSM tries to use the default port.
-p, --port          This option displays a menu of possible local port  GUID
                    values with which osmtest could bind

-i, --inventory     This  option  specifies the name of the inventory file Nor-
                    mally, osmtest expects to find an inventory file, which
                    osmtest uses to validate real-time information received from
                    the SA during testing. If -i  is  not  specified,  osmtest
                    defaults  to  the  file osmtest.dat.
                    See -c option for related information

-s, --stress        This option runs the specified stress test instead of the
                    normal test suite Stress test options are as follows:
                    OPT    Description
                    ---    -----------------
```

```
                    -s1    Single-MAD response SA queries
                    -s2    Multi-MAD (RMPP) response SA queries
                    -s3    Multi-MAD (RMPP) Path Record SA queries
                    Without -s, stress testing is not performed

-M, --Multicast_ModeThis option specify length of Multicast test:
                    OPT    Description
                    ---    -----------------
                    -M1    Short Multicast Flow (default) - single mode
                    -M2    Short Multicast Flow - multiple mode
                    -M3    Long Multicast Flow - single mode
                    -M4    Long Multicast Flow - multiple mode

                    Single mode - Osmtest is tested alone, with no other  apps
                    that interact with OpenSM MC
                    Multiple  mode  -  Could  be  run  with other apps using MC
                    with OpenSM. Without -M, default flow testing is performed

-t, --timeout       This option specifies the time in milliseconds used for
                    transaction  timeouts.  Specifying -t 0 disables timeouts.
                    Without -t, OpenSM defaults to a timeout value of 200 milli-
                    seconds.

-l, --log_file      This option defines the log to be the given  file.   By
                    default the log goes to /var/log/osm.log.  For the log to go
                    to standard output use -f stdout.

-v, --verbose       This option increases the log verbosity level.   The  -v
                    option may  be  specified  multiple  times to further
                    increase the verbosity level.  See the -vf option for  more
                    information  about log verbosity.

-V                  This  option  sets  the  maximum  verbosity level and forces
                    log flushing.  The -V is equivalent to '-vf 0xFF -d 2'.  See
                    the -vf option for more information about log verbosity.

-vf                 This  option  sets  the log verbosity level.  A flags field
                    must follow the -D option.  A bit set/clear in the flags
                    enables/disables a specific log level as follows:
                    BIT    LOG LEVEL ENABLED
                    ----   -----------------
                    0x01 - ERROR (error messages)
                    0x02 - INFO (basic messages, low volume)
                    0x04 - VERBOSE (interesting stuff, moderate volume)
                    0x08 - DEBUG (diagnostic, high volume)
                    0x10 - FUNCS (function entry/exit, very high volume)
                    0x20 - FRAMES (dumps all SMP and GMP frames)
```

```
                    0x40 - ROUTING (dump FDB routing information)
                    0x80 - currently unused.

                    Without  -vf,  osmtest defaults to ERROR + INFO (0x3) Speci-
                    fying -vf 0 disables all messages Specifying -vf 0xFF
                    enables all messages  (see -V) High verbosity levels may
                    require increasing the transaction timeout with the -t
                    option

-h, --help          Display this usage info then exit.
```

9.3.2 Running osmtest

To run **osmtest** in the default mode, simply enter:

```
host1# osmtest
```

The default mode runs all the flows except for the Quality of Service flow (see Section 9.6).

After installing **opensm** (and if the InfiniBand fabric is stable), it is recommended to run the following command in order to generate the inventory file:

```
host1# osmtest -f c
```

Immediately afterwards, run the following command to test **opensm**:

```
host1# osmtest -f a
```

Finally, it is recommended to occasionally run "**`osmtest -v`**" (with verbosity) to verify that nothing in the fabric has changed.

9.4 Partitions

OpenSM enables the configuration of partitions (PKeys) in an InfiniBand fabric. By default, OpenSM searches for the partitions configuration file under the name `/usr/etc/opensm/partitions.conf`. To change this filename, you can use **opensm** with the '--Pconfig' or '-P' flags.

The default partition is created by OpenSM unconditionally, even when a partition configuration file does not exist or cannot be accessed.

The default partition has a P_Key value of 0x7fff. The port out of which runs OpenSM is assigned full membership in the default partition. All other end-ports are assigned partial membership.

9.4.1 File Format

Notes:

- Line content followed after '#' character is comment and ignored by parser.

General File Format

```
<Partition Definition>:<PortGUIDs list> ;
```

Partition Definition:

```
[PartitionName][=PKey][,flag[=value]][,defmember=full|limited]
```

where

PartitionName	string, will be used with logging. When omitted, an empty string will be used.
PKey	P_Key value for this partition. Only low 15 bits will be used. When omitted, P_Key will be autogenerated.
flag	used to indicate IPoIB capability of this partition.
defmember=full|limited	specifies default membership for port guid list. Default is limited.

Currently recognized flags are:

ipoib	indicates that this partition may be used for IPoIB, as a result IPoIB capable MC group will be created.
rate=<val>	specifies rate for this IPoIB MC group (default is 3 (10GBps))
mtu=<val>	specifies MTU for this IPoIB MC group (default is 4 (2048))
sl=<val>	specifies SL for this IPoIB MC group (default is 0)
scope=<val>	specifies scope for this IPoIB MC group (default is 2 (link local))

Note that values for rate, mtu, and scope should be specified as defined in the IBTA specification (for example, mtu=4 for 2048).

PortGUIDs list:

PortGUID	GUID of partition member EndPort. Hexadecimal numbers should start from 0x, decimal numbers are accepted too.
full or limited	indicates full or limited membership for this port. When omitted (or unrecognized) limited membership is assumed.

There are two useful keywords for PortGUID definition:

- 'ALL' means all end-ports in this subnet
- 'SELF' means subnet manager's port

An empty list means that there are no ports in this partition.

Notes:

- White space is permitted between delimiters ('=', ',',':',';').
- The line can be wrapped after ':' after a Partition Definition and between.
- A PartitionName *does not* need to be unique, but PKey *does* need to be unique.
- If a PKey is repeated then the associated partition configurations will be merged and the first PartitionName will be used (see also next note).

- It is possible to split a partition configuration in more than one definition, but then they PKey should be explicitly specified (otherwise different PKey values will be generated for those definitions).

Examples:

```
Default=0x7fff : ALL, SELF=full ;
NewPartition , ipoib : 0x123456=full, 0x3456789034=limi,  0x2134af2306;

YetAnotherOne = 0x300 : SELF=full ;
YetAnotherOne = 0x300 : ALL=limited ;

ShareIO = 0x80 , defmember=full : 0x123451, 0x123452;
# 0x123453, 0x123454 will be limited
ShareIO = 0x80 : 0x123453, 0x123454, 0x123455=full;
# 0x123456, 0x123457 will be limited
ShareIO   =   0x80   :   defmember=limited   :   0x123456,   0x123457,
              0x123458=full;
ShareIO = 0x80 , defmember=full : 0x123459, 0x12345a;
ShareIO  =  0x80  ,  defmember=full  :   0x12345b,   0x12345c=limited,
            0x12345d;
```

Note: The following rule is equivalent to how OpenSM used to run prior to the partition manager:

```
Default=0x7fff,ipoib:ALL=full;
```

9.5 Routing Algorithms

OpenSM offers five routing engines:

1. Min Hop algorithm

   Based on the minimum hops to each node where the path length is optimized.

2. UPDN Unicast routing algorithm

   Based on the minimum hops to each node, but it is constrained to ranking rules. This algorithm should be chosen if the subnet is not a pure Fat Tree, and a deadlock may occur due to a loop in the subnet.

3. Fat Tree Unicast routing algorithm

   This algorithm optimizes routing for a congestion-free "shift" communication pattern. It should be chosen if a subnet is a symmetrical Fat Tree of various types, not just a K-ary-N-Tree: non-constant K, not fully staffed, and for any CBB ratio. Similar to UPDN, Fat Tree routing is constrained to ranking rules.

4. LASH Unicast routing algorithm

   Uses InfiniBand virtual layers (SL) to provide deadlock-free shortest-path routing while also distributing the paths between layers. LASH is an alternative deadlock-free, topology-agnostic routing algorithm to the non-minimal UPDN algorithm. It avoids the use of a potentially congested root node.

5. DOR Unicast routing algorithm

   Based on the Min Hop algorithm, but avoids port equalization except for redundant links between the same two switches. This provides deadlock free routes for hypercubes when the fabric is cabled as a hypercube and for meshes when cabled as a mesh.

OpenSM also supports a file method which can load routes from a table – see Modular Routing Engine below.

The basic routing algorithm is comprised of two stages:

1. MinHop matrix calculation

   How many hops are required to get from each port to each LID? The algorithm to fill these tables is different if you run standard (min hop) or Up/Down. For standard routing, a "relaxation" algorithm is used to propagate min hop from every destination LID through neighbor switches. For Up/Down routing, a BFS from every target is used. The BFS tracks link direction (up or down) and avoid steps that will perform up after a down step was used.

2. Once MinHop matrices exist, each switch is visited and for each target LID a decision is made as to what port should be used to get to that LID. This step is common to standard and Up/Down routing. Each port has a counter counting the number of target LIDs going through it. When there are multiple alternative ports with same MinHop to a LID, the one with less previously assigned ports is selected.

   If LMC > 0, more checks are added. Within each group of LIDs assigned to same target port:

   a. Use only ports which have same MinHop

   b. First prefer the ones that go to different systemImageGuid (then the previous LID of the same LMC group)

   c. If none, prefer those which go through another NodeGuid

   d. Fall back to the number of paths method (if all go to same node).

9.5.1 Effect of Topology Changes

OpenSM will preserve existing routing in any case where there is no change in the fabric switches unless the -r (--reassign_lids) option is specified.

```
-r, --reassign_lids
                This option causes OpenSM to reassign LIDs to all end nodes.
                Specifying -r on a running subnet may disrupt subnet traf-
                fic. Without -r, OpenSM attempts to preserve existing LID
                assignments resolving multiple use of same LID.
```

If a link is added or removed, OpenSM does not recalculate the routes that do not have to change. A route has to change if the port is no longer UP or no longer the MinHop. When routing changes are performed, the same algorithm for balancing the routes is invoked.

In the case of using the file based routing, any topology changes are currently ignored The 'file' routing engine just loads the LFTs from the file specified, with no reaction to real topology. Obviously, this will not be able to recheck LIDs (by GUID) for disconnected nodes, and LFTs for nonexistent switches will be skipped. Multicast is not affected by 'file' routing engine (this uses min hop tables).

9.5.2 Min Hop Algorithm

The Min Hop algorithm is invoked when neither UPDN or the file method are specified. The Min Hop algorithm is divided into two stages: computation of minhop tables on every switch and LFT output port assignment. Link subscription is also equalized with the ability to override based on port GUID. The latter is supplied by:

```
-i <equalize-ignore-guids-file>
-ignore-guids <equalize-ignore-guids-file>
                This option provides the means to define a set of ports (by
                guid) that will be ignored by the link load equalization
```

```
algorithm. Note that only endports (CA, switch port 0, and
router ports) and not switch external ports are supported.
```

LMC awareness routes based on (remote) system or switch basis.

9.5.3 Purpose of UPDN Algorithm

The UPDN algorithm is designed to prevent deadlocks from occurring in loops of the subnet. A loop-deadlock is a situation in which it is no longer possible to send data between any two hosts connected through the loop. As such, the UPDN routing algorithm should be used if the subnet is not a pure Fat Tree, and one of its loops may experience a deadlock (due, for example, to high pressure).

The UPDN algorithm is based on the following main stages:

1. Auto-detect root nodes - based on the CA hop length from any switch in the subnet, a statistical histogram is built for each switch (hop num vs number of occurrences). If the histogram reflects a specific column (higher than others) for a certain node, then it is marked as a root node. Since the algorithm is statistical, it may not find any root nodes. The list of the root nodes found by this auto-detect stage is used by the ranking process stage.

   Note: The user can override the node list manually.

   Note: If this stage cannot find any root nodes, and the user did not specify a guid list file, OpenSM defaults back to the Min Hop routing algorithm.

2. Ranking process - All root switch nodes (found in stage 1) are assigned a rank of 0. Using the BFS algorithm, the rest of the switch nodes in the subnet are ranked incrementally. This ranking aids in the process of enforcing rules that ensure loop-free paths.
3. Min Hop Table setting - after ranking is done, a BFS algorithm is run from each (CA or switch) node in the subnet. During the BFS process, the FDB table of each switch node traversed by BFS is updated, in reference to the starting node, based on the ranking rules and guid values.

At the end of the process, the updated FDB tables ensure loop-free paths through the subnet.

Note: Up/Down routing does not allow LID routing communication between switches that are located inside spine "switch systems". The reason is that there is no way to allow a LID route between them that does not break the Up/Down rule. One ramification of this is that you cannot run SM on switches other than the leaf switches of the fabric.

9.5.3.1 UPDN Algorithm Usage

Activation through OpenSM

- Use '-R updn' option (instead of old '-u') to activate the UPDN algorithm.
- Use '-a <root_guid_file>' for adding an UPDN guid file that contains the root nodes for ranking. If the `-a' option is not used, OpenSM uses its auto-detect root nodes algorithm.

Notes on the guid list file:

1. A valid guid file specifies one guid in each line. Lines with an invalid format will be discarded.
2. The user should specify the root switch guids. However, it is also possible to specify CA guids; OpenSM will use the guid of the switch (if it exists) that connects the CA to the subnet as a root node.

9.5.4 Fat-tree Routing Algorithm

The fat-tree algorithm optimizes routing for "shift" communication pattern. It should be chosen if a subnet is a symmetrical or almost symmetrical fat-tree of various types. It supports not just K-ary-N-Trees, by handling for non-constant K, cases where not all leafs (CAs) are present, any CBB ratio. As in UPDN, fat-tree also prevents credit-loop-deadlocks.

If the root guid file is not provided ('-a' or '--root_guid_file' options), the topology has to be pure fat-tree that complies with the following rules:

- Tree rank should be between two and eight (inclusively)
- Switches of the same rank should have the same number of UP-going port groups[1], unless they are root switches, in which case the shouldn't have UP-going ports at all.
- Switches of the same rank should have the same number of DOWN-going port groups, unless they are leaf switches.
- Switches of the same rank should have the same number of ports in each UP-going port group.
- Switches of the same rank should have the same number of ports in each DOWN-going port group.
- All the CAs have to be at the same tree level (rank).

If the root guid file is provided, the topology doesn't have to be pure fat-tree, and it should only comply with the following rules:

- Tree rank should be between two and eight (inclusively)
- All the Compute Nodes[2] have to be at the same tree level (rank). Note that non-compute node CAs are allowed here to be at different tree ranks.

Topologies that do not comply cause a fallback to min hop routing. Note that this can also occur on link failures which cause the topology to no longer be a “pure” fat-tree.

Note that although fat-tree algorithm supports trees with non-integer CBB ratio, the routing will not be as balanced as in case of integer CBB ratio. In addition to this, although the algorithm allows leaf switches to have any number of CAs, the closer the tree is to be fully populated, the more effective the "shift" communication pattern will be. In general, even if the root list is provided, the closer the topology to a pure and symmetrical fat-tree, the more optimal the routing will be.

The algorithm also dumps compute node ordering file (`opensm-ftree-ca-order.dump`) in the same directory where the OpenSM log resides. This ordering file provides the CN order that may be used to create efficient communication pattern, that will match the routing tables.

Activation through OpenSM

- Use ‘-R ftree’ option to activate the fat-tree algorithm.

1. Ports that are connected to the same remote switch are referenced as ‘port group’
2. List of compute nodes (CNs) can be specified by ‘-u’ or ‘--cn_guid_file’ OpenSM options.

- Use '-a <root_guid_file>' to provide root nodes for ranking. If the '-a' option is not used, routing algorithm will detect roots automatically.
- Use '-u <root_cn_file>' to provide the list of compute nodes. If the '-u' option is not used, all the CAs are considered as compute nodes.

Note: LMC > 0 is not supported by fat-tree routing. If this is specified, the default routing algorithm is invoked instead.

9.5.5 LASH Routing Algorithm

LASH is an acronym for LAyered SHortest Path Routing. It is a deterministic shortest path routing algorithm that enables topology agnostic deadlock-free routing within communication networks.

When computing the routing function, LASH analyzes the network topology for the shortest-path routes between all pairs of sources / destinations and groups these paths into virtual layers in such a way as to avoid deadlock.

Note: LASH analyzes routes and ensures deadlock freedom between switch pairs. The link from HCA between and switch does not need virtual layers as deadlock will not arise between switch and HCA.

In more detail, the algorithm works as follows:

1. LASH determines the shortest-path between all pairs of source / destination switches. Note, LASH ensures the same SL is used for all SRC/DST - DST/SRC pairs and there is no guarantee that the return path for a given DST/SRC will be the reverse of the route SRC/DST.
2. LASH then begins an SL assignment process where a route is assigned to a layer (SL) if the addition of that route does not cause deadlock within that layer. This is achieved by maintaining and analysing a channel dependency graph for each layer. Once the potential addition of a path could lead to deadlock, LASH opens a new layer and continues the process.
3. Once this stage has been completed, it is highly likely that the first layers processed will contain more paths than the latter ones. To better balance the use of layers, LASH moves paths from one layer to another so that the number of paths in each layer averages out.

Note that the implementation of LASH in opensm attempts to use as few layers as possible. This number can be less than the number of actual layers available.

In general LASH is a very flexible algorithm. It can, for example, reduce to Dimension Order Routing in certain topologies, it is topology agnostic and fares well in the face of faults.

It has been shown that for both regular and irregular topologies, LASH outperforms Up/Down. The reason for this is that LASH distributes the traffic more evenly through a network, avoiding the bottleneck issues related to a root node and always routes shortest-path.

The algorithm was developed by Simula Research Laboratory.

Use '-R lash -Q' option to activate the LASH algorithm

Note: QoS support has to be turned on in order that SL/VL mappings are used.

Note: LMC > 0 is not supported by the LASH routing. If this is specified, the default routing algorithm is invoked instead.

9.5.6 DOR Routing Algorithm

The Dimension Order Routing algorithm is based on the Min Hop algorithm and so uses shortest paths. Instead of spreading traffic out across different paths with the same shortest distance, it chooses among the available shortest paths based on an ordering of dimensions. Each port must be consistently cabled to represent a hypercube dimension or a mesh dimension. Paths are grown from a destination back to a source using the lowest dimension (port) of available paths at each step. This provides the ordering necessary to avoid deadlock. When there are multiple links between any two switches, they still represent only one dimension and traffic is balanced across them unless port equalization is turned off. In the case of hypercubes, the same port must be used throughout the fabric to represent the hypercube dimension and match on both ends of the cable. In the case of meshes, the dimension should consistently use the same pair of ports, one port on one end of the cable, and the other port on the other end, continuing along the mesh dimension.

Use ‘-R dor’ option to activate the DOR algorithm.

9.5.7 Routing References

To learn more about deadlock-free routing, see the article “Deadlock Free Message Routing in Multiprocessor Interconnection Networks” by William J Dally and Charles L Seitz (1985).

To learn more about the up/down algorithm, see the article “Effective Strategy to Compute Forwarding Tables for InfiniBand Networks” by Jose Carlos Sancho, Antonio Robles, and Jose Duato at the Universidad Politecnica de Valencia.

To learn more about LASH and the flexibility behind it, the requirement for layers, performance comparisons to other algorithms, see the following articles:

- “Layered Routing in Irregular Networks”, Lysne et al, IEEE Transactions on Parallel and Distributed Systems, VOL.16, No12, December 2005.
- “Routing for the ASI Fabric Manager”, Solheim et al. IEEE Communications Magazine, Vol.44, No.7, July 2006.
- “Layered Shortest Path (LASH) Routing in Irregular System Area Networks", Skeie et al. IEEE Computer Society Communication Architecture for Clusters 2002.

9.5.8 Modular Routine Engine

Modular routing engine structure allows for the ease of “plugging” new routing modules. Currently, only unicast callbacks are supported. Multicast can be added later.

One existing routing module is up-down "updn", which may be activated with '-R updn' option (instead of old '-u').

General usage is:

```
host1# opensm -R 'module-name'
```

There is also a trivial routing module which is able to load LFT tables from a dump file.

Main features are:

- This will load switch LFTs and/or LID matrices (min hops tables)
- This will load switch LFTs according to the path entries introduced in the dump file

- No additional checks will be performed (such as "is port connected", etc.)
- In case when fabric LIDs were changed this will try to reconstruct LFTs correctly if endport GUIDs are represented in the dump file (in order to disable this, GUIDs may be removed from the dump file or zeroed)

The dump file format is compatible with output of 'ibroute' utility and for whole fabric can be generated with dump_lfts.sh script.

To activate file based routing module, use:

```
host1# opensm -R file -U /path/to/dump_file
```

If the dump_file is not found or is in error, the default routing algorithm is utilized. The ability to dump switch lid matrices (aka min hops tables) to file and later to load these is also supported.

The usage is similar to unicast forwarding tables loading from dump file (introduced by 'file' routing engine), but new lid matrix file name should be specified by `-M` or `--lid_matrix_file` option. For example:

```
host1# opensm -R file -M ./opensm-lid-matrix.dump
```

The dump file is named `'opensm-lid-matrix.dump'` and will be generated in the standard opensm dump directory (`/var/log` by default) when OSM_LOG_ROUTING logging flag is set. When routing engine 'file' is activated, but the dump file is not specified or cannot be opened, the default lid matrix algorithm will be used.

There is also a switch forwarding tables dumper which generates a file compatible with dump_lfts.sh output. This file can be used as input for forwarding tables loading by 'file' routing engine. Both or one of options -U and -M can be specified together with '-R file'.

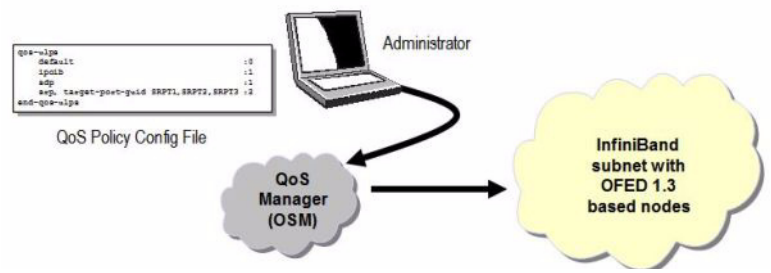
9.6 Quality of Service Management in OpenSM

9.6.1 Overview

When Quality of Service (QoS) in OpenSM is enabled (using the '-Q' or '--qos' flags), OpenSM looks for a QoS Policy file. During fabric initialization and at every heavy sweep, OpenSM parses the QoS policy file, applies its settings to the discovered fabric elements, and enforces the provided policy on client requests. The overall flow for such requests is as follows:

- The request is matched against the defined matching rules such that the QoS Level definition is found
- Given the QoS Level, a path(s) search is performed with the given restrictions imposed by that level

Figure 3: QoS Manager



There are two ways to define QoS policy:

- Advanced – the advanced policy file syntax provides the administrator various ways to match a PathRecord/MultiPathRecord (PR/MPR) request, and to enforce various QoS constraints on the requested PR/MPR
- Simple – the simple policy file syntax enables the administrator to match PR/MPR requests by various ULPs and applications running on top of these ULPs

9.6.2 Advanced QoS Policy File

The QoS policy file has the following sections:

I) Port Groups (denoted by port-groups)

This section defines zero or more port groups that can be referred later by matching rules (see below). Port group lists ports by:

- Port GUID
- Port name, which is a combination of NodeDescription and IB port number
- PKey, which means that all the ports in the subnet that belong to partition with a given PKey belong to this port group
- Partition name, which means that all the ports in the subnet that belong to partition with a given name belong to this port group
- Node type, where possible node types are: CA, SWITCH, ROUTER, ALL, and SELF (SM's port).

II) QoS Setup (denoted by qos-setup)

This section describes how to set up SL2VL and VL Arbitration tables on various nodes in the fabric. However, this is not supported in OFED 1.3. SL2VL and VLArb tables should be configured in the OpenSM options file (default location - /var/cache/opensm/opensm.opts).

III) QoS Levels (denoted by qos-levels)

Each QoS Level defines Service Level (SL) and a few optional fields:

- MTU limit
- Rate limit
- PKey
- Packet lifetime

When path(s) search is performed, it is done with regards to restriction that these QoS Level parameters impose. One QoS level that is mandatory to define is a DEFAULT QoS level. It is applied to a PR/MPR query that does not match any existing match rule. Similar to any other QoS Level, it can also be explicitly referred by any match rule.

IV) QoS Matching Rules (denoted by qos-match-rules)

Each PathRecord/MultiPathRecord query that OpenSM receives is matched against the set of matching rules. Rules are scanned in order of appearance in the QoS policy file such as the first match takes precedence.

Each rule has a name of QoS level that will be applied to the matching query. A default QoS level is applied to a query that did not match any rule.

Queries can be matched by:

- Source port group (whether a source port is a member of a specified group)
- Destination port group (same as above, only for destination port)
- PKey
- QoS class
- Service ID

To match a certain matching rule, PR/MPR query has to match ALL the rule's criteria. However, not all the fields of the PR/MPR query have to appear in the matching rule.

For instance, if the rule has a single criterion - Service ID, it will match any query that has this Service ID, disregarding rest of the query fields. However, if a certain query has only Service ID (which means that this is the only bit in the PR/MPR component mask that is on), it will not match any rule that has other matching criteria besides Service ID.

9.6.3 Simple QoS Policy Definition

Simple QoS policy definition comprises of a single section denoted by qos-ulps. Similar to the advanced QoS policy, it has a list of match rules and their QoS Level, but in this case a match rule has only one criterion - its goal is to match a certain ULP (or a certain application on top of this ULP) PR/MPR request, and QoS Level has only one constraint - Service Level (SL).

The simple policy section may appear in the policy file in combine with the advanced policy, or as a stand-alone policy definition. See more details and list of match rule criteria below.

9.6.4 Policy File Syntax Guidelines

- Leading and trailing blanks, as well as empty lines, are ignored, so the indentation in the example is just for better readability.
- Comments are started with the pound sign (#) and terminated by EOL.
- Any keyword should be the first non-blank in the line, unless it's a comment.
- Keywords that denote section/subsection start have matching closing keywords.
- Having a QoS Level named "DEFAULT" is a must - it is applied to PR/MPR requests that didn't match any of the matching rules.
- Any section/subsection of the policy file is optional.

9.6.5 Examples of Advanced Policy File

As mentioned earlier, any section of the policy file is optional, and the only mandatory part of the policy file is a default QoS Level.

Here's an example of the shortest policy file:

```
    qos-levels
        qos-level
            name: DEFAULT
            sl: 0
        end-qos-level
    end-qos-levels
```

Port groups section is missing because there are no match rules, which means that port groups are not referred anywhere, and there is no need defining them. And since this policy file doesn't have any matching rules, PR/MPR query will not match any rule, and OpenSM will enforce default QoS level. Essentially, the above example is equivalent to not having a QoS policy file at all.

The following example shows all the possible options and keywords in the policy file and their syntax:

```
    #
    # See the comments in the following example.
    # They explain different keywords and their meaning.
    #
    port-groups

        port-group # using port GUIDs
            name: Storage
            # "use" is just a description that is used for logging
            #  Other than that, it is just a comment
            use: SRP Targets
           port-guid: 0x10000000000001, 0x10000000000005-0x1000000000FFFA
            port-guid: 0x1000000000FFFF
        end-port-group

        port-group
            name: Virtual Servers
            # The syntax of the port name is as follows:
            #   "node_description/Pnum".
            # node_description is compared to the NodeDescription of the
node,
            # and "Pnum" is a port number on that node.
            port-name: vs1 HCA-1/P1, vs2 HCA-1/P1
        end-port-group

        # using partitions defined in the partition policy
        port-group
            name: Partitions
            partition: Part1
            pkey: 0x1234
        end-port-group

        # using node types: CA, ROUTER, SWITCH, SELF (for node that runs
SM)
        # or ALL (for all the nodes in the subnet)
        port-group
            name: CAs and SM
            node-type: CA, SELF
        end-port-group

    end-port-groups
```

```
    qos-setup
        # This section of the policy file describes how to set up SL2VL
and VL
        # Arbitration tables on various nodes in the fabric.
        # However, this is not supported in OFED 1.3 - the section is
parsed
        # and ignored. SL2VL and VLArb tables should be configured in the
        # OpenSM options file (by default - /var/cache/opensm/
opensm.opts).
    end-qos-setup

    qos-levels

        # Having a QoS Level named "DEFAULT" is a must - it is applied to
        # PR/MPR requests that didn't match any of the matching rules.
        qos-level
            name: DEFAULT
            use: default QoS Level
            sl: 0
        end-qos-level

        # the whole set: SL, MTU-Limit, Rate-Limit, PKey, Packet Lifetime
        qos-level
            name: WholeSet
            sl: 1
            mtu-limit: 4
            rate-limit: 5
            pkey: 0x1234
            packet-life: 8
        end-qos-level

    end-qos-levels

    # Match rules are scanned in order of their apperance in the policy
file.
    # First matched rule takes precedence.
    qos-match-rules

        # matching by single criteria: QoS class
        qos-match-rule
            use: by QoS class
            qos-class: 7-9,11
            # Name of qos-level to apply to the matching PR/MPR
            qos-level-name: WholeSet
        end-qos-match-rule

        # show matching by destination group and service id
        qos-match-rule
            use: Storage targets
            destination: Storage
            service-id: 0x10000000000001, 0x10000000000008-
0x10000000000FFF
            qos-level-name: WholeSet
        end-qos-match-rule

        qos-match-rule
            source: Storage
            use: match by source group only
            qos-level-name: DEFAULT
```

```
        end-qos-match-rule

        qos-match-rule
            use: match by all parameters
            qos-class: 7-9,11
            source: Virtual Servers
            destination: Storage
            service-id: 0x0000000000010000-0x000000000001FFFF
            pkey: 0x0F00-0x0FFF
            qos-level-name: WholeSet
        end-qos-match-rule

    end-qos-match-rules
```

9.6.6 Simple QoS Policy - Details and Examples

Simple QoS policy match rules are tailored for matching ULPs (or some application on top of a ULP) PR/MPR requests. This section has a list of per-ULP (or per-application) match rules and the SL that should be enforced on the matched PR/MPR query.

Match rules include:

- Default match rule that is applied to PR/MPR query that didn't match any of the other match rules
- SDP
- SDP application with a specific target TCP/IP port range
- SRP with a specific target IB port GUID
- RDS
- iSER
- iSER application with a specific target TCP/IP port range
- IPoIB with a default PKey
- IPoIB with a specific PKey
- Any ULP/application with a specific Service ID in the PR/MPR query
- Any ULP/application with a specific PKey in the PR/MPR query
- Any ULP/application with a specific target IB port GUID in the PR/MPR query

Since any section of the policy file is optional, as long as basic rules of the file are kept (such as no referring to nonexisting port group, having default QoS Level, etc), the simple policy section (qos-ulps) can serve as a complete QoS policy file.

The shortest policy file in this case would be as follows:

```
qos-ulps
    default  : 0 #default SL
end-qos-ulps
```

It is equivalent to the previous example of the shortest policy file, and it is also equivalent to not having policy file at all. Below is an example of simple QoS policy with all the possible keywords:

```
qos-ulps
```

```
    default                          : 0 # default SL
    sdp, port-num 30000              : 0 # SL for application running on
                                         # top of SDP when a destination
                                         # TCP/IPport is 30000
    sdp, port-num 10000-20000        : 0
    sdp                              : 1 # default SL for any other
                                        # application running on top of SDP
    rds                              : 2 # SL for RDS traffic
    iser, port-num 900               : 0 # SL for iSER with a specific
                                         # target port
    iser                             : 3 # default SL for iSER
    ipoib, pkey 0x0001              : 0 # SL for IPoIB on partition with
                                         # pkey 0x0001
    ipoib                            : 4 # default IPoIB partition,
                                         # pkey=0x7FFF
    any, service-id 0x6234           : 6 # match any PR/MPR query with a
                                         # specific Service ID
    any, pkey 0x0ABC                 : 6 # match any PR/MPR query with a
                                         # specific PKey
   srp, target-port-guid 0x1234  : 5 # SRP when SRP Target is located
                                         # on a specified IB port GUID
    any, target-port-guid 0x0ABC-0xFFFFF : 6 # match any PR/MPR query
                                      # with a specific target port GUID
end-qos-ulps
```

Similar to the advanced policy definition, matching of PR/MPR queries is done in order of appearance in the QoS policy file such as the first match takes precedence, except for the "default" rule, which is applied only if the query didn't match any other rule. All other sections of the QoS policy file take precedence over the qos-ulps section. That is, if a policy file has both qos-match-rules and qos-ulps sections, then any query is matched first against the rules in the qos-match-rules section, and only if there was no match, the query is matched against the rules in qos-ulps section.

Note that some of these match rules may overlap, so in order to use the simple QoS definition effectively, it is important to understand how each of the ULPs is matched.

9.6.6.1 IPoIB

IPoIB query is matched by PKey or by destination GID, in which case this is the GID of the multicast group that OpenSM creates for each IPoIB partition.

Default PKey for IPoIB partition is 0x7fff, so the following three match rules are equivalent:

```
ipoib              : <SL>
ipoib, pkey 0x7fff : <SL>
any,   pkey 0x7fff : <SL>
```

9.6.6.2 SDP

SDP PR query is matched by Service ID. The Service-ID for SDP is 0x000000000001PPPP, where PPPP are 4 hex digits holding the remote TCP/IP Port Number to connect to. The following two match rules are equivalent:

```
sdp                                                  : <SL>
```

```
any, service-id 0x0000000000010000-0x000000000001ffff : <SL>
```

9.6.6.3 RDS

Similar to SDP, RDS PR query is matched by Service ID. The Service ID for RDS is 0x000000000106PPPP, where PPPP are 4 hex digits holding the remote TCP/IP Port Number to connect to. Default port number for RDS is 0x48CA, which makes a default Service-ID 0x00000000010648CA. The following two match rules are equivalent:

```
rds                                 : <SL>
any, service-id 0x00000000010648CA : <SL>
```

9.6.6.4 iSER

Similar to RDS, iSER query is matched by Service ID, where the the Service ID is also 0x000000000106PPPP. Default port number for iSER is 0x035C, which makes a default Service-ID 0x000000000106035C. The following two match rules are equivalent:

```
iser                                : <SL>
any, service-id 0x000000000106035C : <SL>
```

9.6.6.5 SRP

Service ID for SRP varies from storage vendor to vendor, thus SRP query is matched by the target IB port GUID. The following two match rules are equivalent:

```
srp, target-port-guid 0x1234  : <SL>
any, target-port-guid 0x1234  : <SL>
```

Note that any of the above ULPs might contain target port GUID in the PR query, so in order for these queries not to be recognized by the QoS manager as SRP, the SRP match rule (or any match rule that refers to the target port guid only) should be placed at the end of the qos-ulps match rules.

9.6.6.6 MPI

SL for MPI is manually configured by MPI admin. OpenSM is not forcing any SL on the MPI traffic, and that's why it is the only ULP that did not appear in the qos-ulps section.

9.6.7 SL2VL Mapping and VL Arbitration

OpenSM cached options file has a set of QoS related configuration parameters, that are used to configure SL2VL mapping and VL arbitration on IB ports. These parameters are:

- Max VLs: the maximum number of VLs that will be on the subnet
- High limit: the limit of High Priority component of VL Arbitration table (IBA 7.6.9)
- VLArb low table: Low priority VL Arbitration table (IBA 7.6.9) template
- VLArb high table: High priority VL Arbitration table (IBA 7.6.9) template

- SL2VL: SL2VL Mapping table (IBA 7.6.6) template. It is a list of VLs corresponding to SLs 0-15 (Note that VL15 used here means drop this SL).

There are separate QoS configuration parameters sets for various target types: CAs, routers, switch external ports, and switch's enhanced port 0. The names of such parameters are prefixed by "qos_<type>_" string. Here is a full list of the currently supported sets:

- qos_ca_ - QoS configuration parameters set for CAs.
- qos_rtr_ - parameters set for routers.
- qos_sw0_ - parameters set for switches' port 0.
- qos_swe_ - parameters set for switches' external ports.

Here's the example of typical default values for CAs and switches' external ports (hard-coded in OpenSM initialization):

```
qos_ca_max_vls=15
qos_ca_high_limit=0
qos_ca_vlarb_high=0:4,1:0,2:0,3:0,4:0,5:0,6:0,7:0,8:0,9:0,10:0,11:0,12:0
,13:0,14:0
qos_ca_vlarb_low=0:0,1:4,2:4,3:4,4:4,5:4,6:4,7:4,8:4,9:4,10:4,11:4,12:4,
13:4,14:4
qos_ca_sl2vl=0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,7
qos_swe_max_vls=15
qos_swe_high_limit=0
qos_swe_vlarb_high=0:4,1:0,2:0,3:0,4:0,5:0,6:0,7:0,8:0,9:0,10:0,11:0,12:
0,13:0,14:0
qos_swe_vlarb_low=0:0,1:4,2:4,3:4,4:4,5:4,6:4,7:4,8:4,9:4,10:4,11:4,12:4
,13:4,14:4
qos_swe_sl2vl=0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,7
```

VL arbitration tables (both high and low) are lists of VL/Weight pairs. Each list entry contains a VL number (values from 0-14), and a weighting value (values 0-255), indicating the number of 64 byte units (credits) which may be transmitted from that VL when its turn in the arbitration occurs. A weight of 0 indicates that this entry should be skipped. If a list entry is programmed for VL15 or for a VL that is not supported or is not currently configured by the port, the port may either skip that entry or send from any supported VL for that entry.

Note, that the same VLs may be listed multiple times in the High or Low priority arbitration tables, and, further, it can be listed in both tables. The limit of high-priority VLArb table (qos_<type>_high_limit) indicates the number of high-priority packets that can be transmitted without an opportunity to send a low-priority packet. Specifically, the number of bytes that can be sent is high_limit times 4K bytes.

A high_limit value of 255 indicates that the byte limit is unbounded.

Note: If the 255 value is used, the low priority VLs may be starved.

A value of 0 indicates that only a single packet from the high-priority table may be sent before an opportunity is given to the low-priority table.

Keep in mind that ports usually transmit packets of size equal to MTU. For instance, for 4KB MTU a single packet will require 64 credits, so in order to achieve effective VL arbitration for packets of 4KB MTU, the weighting values for each VL should be multiples of 64.

Below is an example of SL2VL and VL Arbitration configuration on subnet:

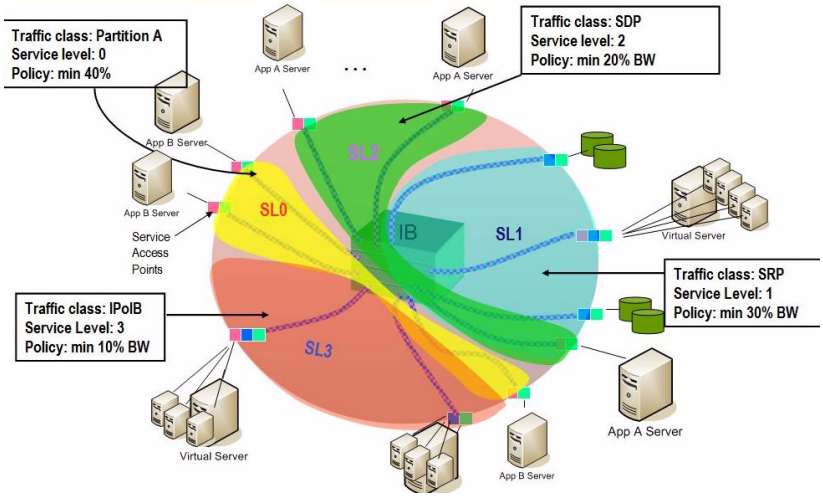
```
qos_ca_max_vls=15
qos_ca_high_limit=6
qos_ca_vlarb_high=0:4
qos_ca_vlarb_low=0:0,1:64,2:128,3:192,4:0,5:64,6:64,7:64
qos_ca_sl2vl=0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,7
qos_swe_max_vls=15
qos_swe_high_limit=6
qos_swe_vlarb_high=0:4
qos_swe_vlarb_low=0:0,1:64,2:128,3:192,4:0,5:64,6:64,7:64
qos_swe_sl2vl=0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,7
```

In this example, there are 8 VLs configured on subnet: VL0 to VL7. VL0 is defined as a high priority VL, and it is limited to 6 x 4KB = 24KB in a single transmission burst. Such configuration would suilt VL that needs low latency and uses small MTU when transmitting packets. Rest of VLs are defined as low priority VLs with different weights, while VL4 is effectively turned off.

9.6.8 Deployment Example

Figure 4 shows an example of an InfiniBand subnet that has been configured by a QoS manager to provide different service levels for various ULPs.

Figure 4: Example QoS Deployment on InfiniBand Subnet



9.7 QoS Configuration Examples

The following are examples of QoS configuration for different cluster deployments. Each example provides the QoS level assignment and their administration via OpenSM configuration files.

9.7.1 Typical HPC Example: MPI and Lustre

Assignment of QoS Levels

- MPI
  - Separate from I/O load
  - Min BW of 70%

- Storage Control (Lustre MDS)
  - Low latency
- Storage Data (Lustre OST)
  - Min BW 30%

Administration

- MPI is assigned an SL via the command line

```
host1# mpirun –sl 0
```

- OpenSM QoS policy file

Note: In the following policy file example, replace OST* and MDS* with the real port GUIDs.

```
qos-ulps
    default                                    :0 # default SL (for MPI)
    any, target-port-guid OST1,OST2,OST3,OST4:1 # SL for Lustre OST
    any, target-port-guid MDS1,MDS2            :2 # SL for Lustre MDS
end-qos-ulps
```

- OpenSM options file

```
qos_max_vls=8
qos_high_limit=0
qos_vlarb_high=2:1
qos_vlarb_low=0:96,1:224
qos_sl2vl=0,1,2,3,4,5,6,7,15,15,15,15,15,15,15,15
```

9.7.2 EDC SOA (2-tier): IPoIB and SRP

The following is an example of QoS configuration for a typical enterprise data center (EDC) with service oriented architecture (SOA), with IPoIB carrying all application traffic and SRP used for storage.

QoS Levels

- Application traffic
  - IPoIB (UD and CM) and SDP
  - Isolated from storage
  - Min BW of 50%
- SRP
  - Min BW 50%
  - Bottleneck at storage nodes

Administration

- OpenSM QoS policy file

Note: In the following policy file example, replace SRPT* with the real SRP Target port GUIDs.

```
qos-ulps
    default                                 :0
    ipoib                                   :1
    sdp                                     :1
    srp, target-port-guid SRPT1,SRPT2,SRPT3 :2
end-qos-ulps
```

- OpenSM options file

```
qos_max_vls=8
 qos_high_limit=0
 qos_vlarb_high=1:32,2:32
 qos_vlarb_low=0:1,
 qos_sl2vl=0,1,2,3,4,5,6,7,15,15,15,15,15,15,15,15
```

9.7.3 EDC (3-tier): IPoIB, RDS, SRP

The following is an example of QoS configuration for an enterprise data center (EDC), with IPoIB carrying all application traffic, RDS for database traffic, and SRP used for storage.

QoS Levels

- Management traffic (ssh)
  - IPoIB management VLAN (partition A)
  - Min BW 10%
- Application traffic
  - IPoIB application VLAN (partition B)
  - Isolated from storage and database
  - Min BW of 30%
- Database Cluster traffic
  - RDS
  - Min BW of 30%
- SRP
  - Min BW 30%
  - Bottleneck at storage nodes

Administration

- OpenSM QoS policy file

Note: In the following policy file example, replace SRPT* with the real SRP Initiator port GUIDs.

```
qos-ulps
    default                                 : 0
    ipoib, pkey 0x8001                      : 1
    ipoib, pkey 0x8002                      : 2
    rds                                     : 3
    srp, target-port-guid SRPT1, SRPT2, SRPT3  : 4
```

```
end-qos-ulps
```

- OpenSM options file

```
qos_max_vls=8
qos_high_limit=0
qos_vlarb_high=1:32,2:96,3:96,4:96
qos_vlarb_low=0:1,
qos_sl2vl=0,1,2,3,4,5,6,7,15,15,15,15,15,15,15,15
```

- Partition configuration file

```
Default=0x7fff, ipoib,      : ALL=full;
PartA=0x8001,   ipoib, sl=1 : ALL=full;
PartB=0x8002,   ipoib, sl=2 : ALL=full;
```

10 Diagnostic Utilities

10.1 Overview

The diagnostic utilities described in this chapter provide means for debugging the connectivity and status of InfiniBand (IB) devices in a fabric. The tools are:

- `ibdiagnet` (described in Section 10.3)
- `ibdiagpath` (described in Section 10.4)

10.2 Utilities Usage

This section first describes common configuration, interface, and addressing for all the tools in the package. Then it provides detailed descriptions of the tools themselves including: operation, synopsis and options descriptions, error codes, and examples.

10.2.1 Common Configuration, Interface and Addressing

Topology File (Optional)

An InfiniBand fabric is composed of switches and channel adapter (HCA/TCA) devices. To identify devices in a fabric (or even in one switch system), each device is given a GUID (a MAC equivalent). Since a GUID is a non-user-friendly string of characters, it is better to alias it to a meaningful, user-given name. For this objective, the IB Diagnostic Tools can be provided with a "topology file", which is an optional configuration file specifying the IB fabric topology in user-given names.

For diagnostic tools to fully support the topology file, the user may need to provide the local system name (if the local hostname is not used in the topology file).

To specify a topology file to a diagnostic tool use one of the following two options:

1. On the command line, specify the file name using the option '`-t <topology file name>`'
2. Define the environment variable IBDIAG_TOPO_FILE

To specify the local system name to an diagnostic tool use one of the following two options:

1. On the command line, specify the system name using the option '`-s <local system name>`'
2. Define the environment variable IBDIAG_SYS_NAME

10.2.2 IB Interface Definition

The diagnostic tools installed on a machine connect to the IB fabric by means of an HCA port through which they send MADs. To specify this port to an IB diagnostic tool use one of the following options:

1. On the command line, specify the port number using the option '-p <local port number>' (see below)

2. Define the environment variable IBDIAG_PORT_NUM

In case more than one HCA device is installed on the local machine, it is necessary to specify the device's index to the tool as well. For this use on of the following options:

1. On the command line, specify the index of the local device using the following option:
   '-i <index of local device>'
2. Define the environment variable IBDIAG_DEV_IDX

10.2.3 Addressing

Note: This section applies to the `ibdiagpath` tool only. A tool command may require defining the destination device or port to which it applies. The following addressing modes can be used to define the IB ports:

- Using a Directed Route to the destination: (Tool option '-d')

  This option defines a directed route of output port numbers from the local port to the destination.

- Using port LIDs: (Tool option '-l'):

  In this mode, the source and destination ports are defined by means of their LIDs. If the fabric is configured to allow multiple LIDs per port, then using any of them is valid for defining a port.

- Using port names defined in the topology file: (Tool option '-n')

  This option refers to the source and destination ports by the names defined in the topology file. (Therefore, this option is relevant only if a topology file is specified to the tool.) In this mode, the tool uses the names to extract the port LIDs from the matched topology, then the tool operates as in the '-l' option.

10.3 ibdiagnet - IB Net Diagnostic

ibdiagnet scans the fabric using directed route packets and extracts all the available information regarding its connectivity and devices. It then produces the following files in the output directory (which is defined by the -o option described below).

10.3.1 SYNOPSYS

```
ibdiagnet [-c <count>] [-v] [-r] [-o <out-dir>] [-t <topo-file>]
          [-s <sys-name>] [-i <dev-index>] [-p <port-num>] [-wt]
          [-pm] [-pc] [-P <<PM>=<Value>>] [-lw <1x|4x|12x>] [-ls <2.5|5|10>]
          [-skip <ibdiag_check/s>] [-load_db <db_file>]
```

OPTIONS:

-c <count>	Min number of packets to be sent across each link (default = 10)
-v	Enable verbose mode
-r	Provides a report of the fabric qualities
-t <topo-file>	Specifies the topology file name
-s <sys-name>	Specifies the local system name. Meaningful only if a topology file is specified

-i <dev-index>	Specifies the index of the device of the port used to connect to the IB fabric (in case of multiple devices on the local system)
-p <port-num>	Specifies the local device's port num used to connect to the IB fabric
-o <out-dir>	Specifies the directory where the output files will be placed (default = /tmp)
-lw <1x|4x|12x>	Specifies the expected link width
-ls <2.5|5|10>	Specifies the expected link speed
-pm	Dump all the fabric links, pm Counters into ibdiagnet.pm
-pc	Reset all the fabric links pmCounters
-P <PM=<Trash>>	If any of the provided pm is greater then its provided value, print it to screen
-skip <skip-option(s)>	Skip the executions of the selected checks. Skip options (one or more can be specified): dup_guids zero_guids pm logical_state part ipoib all
-wt <file-name>	Write out the discovered topology into the given file. This flag is useful if you later want to check for changes from the current state of the fabric. A directory named ibdiag_ibnl is also created by this option, and holds the IBNL files required to load this topology. To use these files you will need to set the environment variable named IBDM_IBNL_PATH to that directory. The directory is located in /tmp or in the output directory provided by the -o flag.
-load_db <file-name>	Load subnet data from the given .db file, and skip subnet discovery stage. Note: Some of the checks require actual subnet discovery, and therefore would not run when load_db is specified. These checks are: Duplicated/zero guids, link state, SMs status.
-h|--help	Prints the help page information
-V|--version	Prints the version of the tool
--vars	Prints the tool's environment variables and their values

10.3.2 Output Files

Table 6 - ibdiagnet Output Files

Output File	Description
ibdiagnet.log	A dump of all the application reports generate according to the provided flags
ibdiagnet.lst	List of all the nodes, ports and links in the fabric
ibdiagnet.fdbs	A dump of the unicast forwarding tables of the fabric switches
ibdiagnet.mcfdbs	A dump of the multicast forwarding tables of the fabric switches
ibdiagnet.masks	In case of duplicate port/node Guids, these file include the map between masked Guid and real Guids
ibdiagnet.sm	List of all the SM (state and priority) in the fabric
ibdiagnet.pm	A dump of the pm Counters values, of the fabric links
ibdiagnet.pkey	A dump of the the existing partitions and their member host ports
ibdiagnet.mcg	A dump of the multicast groups, their properties and member host ports
ibdiagnet.db	A dump of the internal subnet database. This file can be loaded in later runs using the -load_db option

In addition to generating the files above, the discovery phase also checks for duplicate node/port GUIDs in the IB fabric. If such an error is detected, it is displayed on the standard output. After the discovery phase is completed, directed route packets are sent multiple times (according to the -c option) to detect possible problematic paths on which packets may be lost. Such paths are explored, and a report of the suspected bad links is displayed on the standard output.

After scanning the fabric, if the `-r` option is provided, a full report of the fabric qualities is displayed. This report includes:

- SM report
- Number of nodes and systems
- Hop-count information: maximal hop-count, an example path, and a hop-count histogram
- All CA-to-CA paths traced
- Credit loop report
- mgid-mlid-HCAs multicast group and report
- Partitions report
- IPoIB report

Note: In case the IB fabric includes only one CA, then CA-to-CA paths are not reported. Furthermore, if a topology file is provided, ibdiagnet uses the names defined in it for the output reports.

10.3.3 ERROR CODES

```
1 - Failed to fully discover the fabric
2 - Failed to parse command line options
3 - Failed to intract with IB fabric
4 - Failed to use local device or local port
5 - Failed to use Topology File
6 - Failed to load requierd Package
```

10.4 ibdiagpath - IB diagnostic path

`ibdiagpath` traces a path between two end-points and provides information regarding the nodes and ports traversed along the path. It utilizes device specific health queries for the different devices along the path.

The way `ibdiagpath` operates depends on the addressing mode used on the command line. If directed route addressing is used (-d flag), the local node is the source node and the route to the destination port is known apriori. On the other hand, if LID-route (or by-name) addressing is employed, then the source and destination ports of a route are specified by their LIDs (or by the names defined in the topology file). In this case, the actual path from the local port to the source port, and from the source port to the destination port, is defined by means of Subnet Management Linear Forwarding Table queries of the switch nodes along that path. Therefore, the path cannot be predicted as it may change.

`ibdiagpath` should not be supplied with contradicting local ports by the -p and -d flags (see synopsis descriptions below). In other words, when ibdiagpath is provided with the options -p and -d together, the first port in the direct route must be equal to the one specified in the "-p" option. Otherwise, an error is reported.

Note: When `ibdiagpath` queries for the performance counters along the path between the source and destination ports, it always traverses the LID route, even if a directed route is specified. If along the LID route one or more links are not in the ACTIVE state, `ibdiagpath` reports an error.

Moreover, the tool allows omitting the source node in LID-route addressing, in which case the local port on the machine running the tool is assumed to be the source.

10.4.1 SYNOPSYS

```
ibdiagpath {-n <[src-name,]dst-name>|-l <[src-lid,]dst-lid>|
            -d <p1,p2,p3,...>} [-c <count>] [-v] [-t <topo-file>]
            [-s <sys-name>] [-ic<dev-index>]c[-p <port-num>] [-o <out-dir>]
            [-lw <1x|4x|12x>] [-ls <2.5|5|10>][-pm] [-pc]
            [-P <<PM counter>=<Trash Limit>>]
```

OPTIONS:

`-n <[src-name,]dst-name>`
: Names of the source and destination ports (as defined in the topology file; source may be omitted -> local port is assumed to be the source)

`-l <[src-lid,]dst-lid>`
: Source and destination LIDs (source may be omitted --> the local port is assumed to be the source)

`-d <p1,p2,p3,...>`
: Directed route from the local node (which is the source) and the destination node

`-c <count>`
: The minimal number of packets to be sent across each link (default = 100)

`-v`
: Enable verbose mode

`-t <topo-file>`
: Specifies the topology file name

`-s <sys-name>`
: Specifies the local system name. Meaningful only if a topology file is specified

```
-i <dev-index>          Specifies the index of the device of the port used to
                        connect to the IB fabric (in case of multiple devices on
                        the local system)
-p <port-num>           Specifies the local device's port number used to connect
                        to the IB fabric
-o <out-dir>            Specifies the directory where the output files will be
                        placed (default = /tmp)
-lw <1x|4x|12x>         Specifies the expected link width
-ls <2.5|5|10>          Specifies the expected link speed
-pm                     Dump all the fabric links, pm Counters into ibdiagnet.pm
-pc                     Reset all the fabric links pmCounters
-P <PM=<Trash>>         If any of the provided pm is greater then its provided
                        value, print it to screen
-h|--help               Prints the help page information
-V|--version            Prints the version of the tool
--vars                  Prints the tool's environment variables and their values
```

10.4.2 Output Files

Table 7 - ibdiagpath Output Files

Output File	Description
ibdiagpath.log	A dump of all the application reports generated according to the provided flags
ibdiagnet.pm	A dump of the Performance Counters values, of the fabric links

10.4.3 ERROR CODES

```
1 - The path traced is un-healthy
2 - Failed to parse command line options
3 - More then 64 hops are required for traversing the local port to the
    "Source" port and then to the "Destination" port
4 - Unable to traverse the LFT data from source to destination
5 - Failed to use Topology File
6 - Failed to load required Package
```

Appendix A: Boot over IB (BoIB)

A.1 Overview

This chapter describes "Mellanox Boot over IB" (BoIB), the software for Boot over Mellanox Technologies InfiniBand HCA devices. BoIB enables booting kernels or operating systems (OS) from remote servers in compliance with the PXE specification.

BoIB is based on the open source project Etherboot/gPXE available at http://www.etherboot.org.

Etherboot/gPXE first initializes the HCA device. Then, it connects to a DHCP server to obtain its assigned IP address and network parameters, and also to obtain the source location of the kernel/OS to boot from. The DHCP server instructs Etherboot/gPXE to access the kernel/OS through a TFTP server, an iSCSI target, or other media.

Mellanox Boot over IB implements a network driver with IP over IB acting as the transport layer. IP over IB is part of Mellanox OFED for Linux (see www.mellanox.com).

The binary code is exported by the device as an expansion ROM image.

A.2 Supported Mellanox HCA Devices

- ConnectX(TM) IB (Firmware: fw-25408)
- InfiniHost(TM) III Ex (Firmware: fw-25218)
- InfiniHost(TM) III Lx (Firmware: fw-25204)

A.3 Tested Platforms

See the Boot over IB Release Notes (boot_over_ib_release_notes.txt).

A.4 BoIB in Mellanox OFED

The Boot over IB binary files are provided as part of the Mellaox OFED for Linux ISO image. The following binary files are included:

1. PXE binary files for Mellanox HCA devices
   - HCA: ConnectX IB SDR (PCI DevID: 25408)

     `CONNECTX_SDR_PORT1_ROM-1.0.0.rom` (IB Port 1)

     `CONNECTX_SDR_PORT2_ROM-1.0.0.rom` (IB Port 2)

     Location in ISO: `firmware/fw-25408/exp_rom/`
   - HCA: ConnectX IB DDR (PCI DevID: 25418)

     `CONNECTX_DDR_PORT1_ROM-1.0.0.rom` (IB Port 1)

     `CONNECTX_DDR_PORT2_ROM-1.0.0.rom` (IB Port 2)

Location in ISO: `firmware/fw-25418/exp_rom/`

- HCA: InfiniHost III Ex in Mem-Free mode (PCI DevID: 25218)

  `IHOST3EX_PORT1_ROM-1.0.0.rom` (IB Port 1)

  `IHOST3EX_PORT2_ROM-1.0.0.rom` (IB Port 2)

  Location in ISO: `firmware/fw-25218/exp_rom/`

- HCA: InfiniHost III Lx (PCI DevID: 25204)

  `IHOST3LX_ROM-1.0.0.rom` (single IB Port device)

  Location in ISO: `firmware/fw-25204/exp_rom/`

2. Additional files:
   - `dhcpd.conf` - sample DHCP configuration file
   - `dhcp.patch` - patch file for DHCP v3.1.1rc1

   Both files are available under the `docs/` folder.

A.5 Burning the Expansion ROM Image

The binary code resides in the same Flash device of the device firmware. Note that the binary files are distinct and do not affect each other. Mellanox's `mlxburn` tool is available for burning, however it is not possible to burn the expansion ROM image by itself. Rather, both the firmware and expansion ROM images must be burnt simultaneously.

`mlxburn` requires the following items:

1. MST device name

   After installing the MFT package run:

   ```
   mst start
   mst status
   ```

   The device name will be of the form: `/dev/mst/mt<dev_id>_pci{_cr0|conf0}`.

2. The firmware mlx file `fw-25418-X_X_XXX.mlx`
3. One of the expansion ROM binary files listed in Section A.4.

Firmware Burning Example

The following command burns a firmware image and an expansion ROM image to the Flash device of a ConnectX IB HCA Card:

```
mlxburn -dev /dev/mst/mt25418_pci_cr0 -fw fw-25418-X_X_XXX.mlx -exp_rom \
CONNECTX_DDR_PORT1_ROM-RC1.bin
```

Firmware Update Example

To update the expansion ROM image, enter:

```
mlxburn -dev /dev/mst/mt25418_pci_cr0 -fw fw-25418-X_X_XXX.mlx -exp_rom AUTO
```

A.6 Preparing the DHCP Server

The DHCP server plays a major role in the boot process by assigning IP addresses for BoIB clients and instructs the clients where to boot from. Please refer to Section 3.2.1 on page 31 for instructions on how to run the DHCP server.

A.6.1 Configuring the DHCP Server

When a BoIB client boots, it sends the DHCP server various information, including its DHCP client identifier. This identifier is used to distinguish between the various DHCP sessions.

The value of the client identifier is composed of 21 bytes (separated by colons) having the following components:

```
20:<QP Number - 4 bytes>:<GID - 16 bytes>
```

Note: Bytes are represented as two-hexadecimal digits.

Extracting the Client Identifier – Method I

The following steps describe one method for extracting the client identifier:

Step 1. QP Number equals 00:55:04:01 for InfiniHost III Ex and InfiniHost III Lx HCAs, and 00:55:00:41 for ConnectX IB HCAs.

Step 2. GID is composed of an 8-byte subnet prefix and an 8-byte Port GUID. The subnet prefix is fixed for the supported Mellanox HCAs, and is equal to fe:80:00:00:00:00:00:00. The next steps explains how to obtain the Port GUID.

Step 3. To obtain the Port GUID, run the following commands:

Note: The following MFT commands assume that Mellanox OFED has been properly installed on the client machine.

```
host1# mst start
host1# mst status
```

The device name will be of the form: /dev/mst/mt<dev_id>_pci{_cr0|conf0}. Use this device name to obtain the Port GUID via a query command.

```
flint -d <MST_DEVICE_NAME> q
```

Example with InfiniHost III Ex as the HCA device:

```
host1# flint -d /dev/mst/mt25218_pci_cr0 q
Image type:      Failsafe
FW Version:      5.3.0
Rom Info:        type=GPXE version=1.0.0 devid=25218 port=2
I.S. Version:    1
Device ID:       25218
Chip Revision:   A0
Description:  Node          Port1           Port2          Sys image
GUIDs:  0002c90200231390 0002c90200231391 0002c90200231392 0002c90200231393
Board ID:         (MT_0370110001)
VSD:
```

```
PSID:            MT_0370110001
```

Assuming that BoIB is connected via Port 2, then the Port GUID is 00:02:c9:02:00:23:13:92.

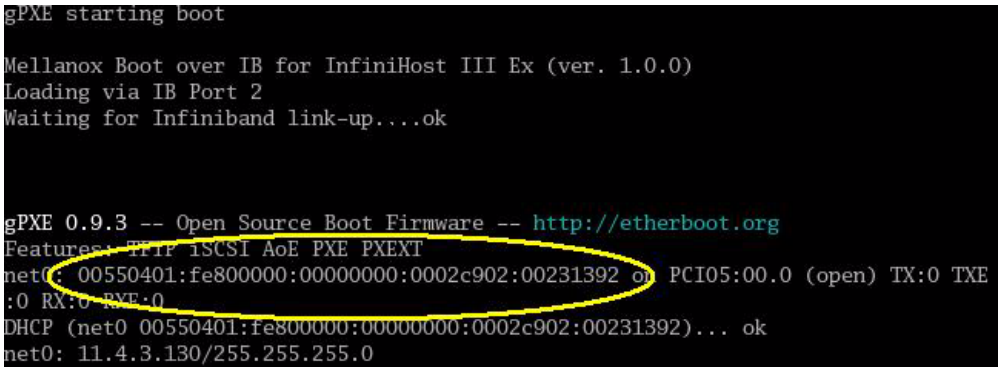
Step 4. The resulting client identifier is the concatenation, from left to right, of 20, the QP_Number, the subnet prefix, and the Port GUID.

In the example above this yields the following DHCP client identifier:

```
20:00:55:04:01:fe:80:00:00:00:00:00:00:00:02:c9:02:00:23:13:92
```

Extracting the Client Identifier – Method II

An alternative method for obtaining the 20 bytes of QP Number and GID involves booting the client machine via BoIB. This requires having a Subnet Manager running on one of the machines in the Infiniband subnet. The 20 bytes can be captured from the boot session as shown in the figure below.



Concatenate the byte ‘20’ to the left of the captured 20 bytes, then separate every byte (two hexadecimal digits) with a colon. You should obtain the same result shown in Step 4 above.

Placing Client Identifiers in /etc/dhcpd.conf

The following is an excerpt of a `/etc/dhcpd.conf` example file showing the format of representing a client machine for the DHCP server.

```
host host1 {
   next-server 11.4.3.7;
   filename "pxelinux.0";
   fixed-address 11.4.3.130;
   option dhcp-client-identifier = \
   20:00:55:04:01:fe:80:00:00:00:00:00:00:00:02:c9:02:00:23:13:92;
}
```

A.7 Subnet Manager – OpenSM

BoIB requires a Subnet Manager to be running on one of the machines in the IB network. OpenSM is part of Mellanox OFED for Linux and can be used to accomplish this. Note that OpenSM may be run on the same host running the DHCP server but it is not mandatory. For details on OpenSM, see Chapter 9.

A.8 TFTP Server

When you set the 'filename' parameter in your DHCP configuration to a non-empty filename, the client will ask for this file to be passed through TFTP. For this reason you need to install a TFTP server.

A.9 BIOS Configuration

The expansion ROM image presents itself to the BIOS as a boot device. As a result, the BIOS will add 'gPXE' to the list of boot devices. The priority of this list can be modified through BIOS setup.

A.10 Operation

A.10.1 Prerequisites

- Make sure that your client is connected to the server(s)
- Burn your client machine with BoIB as described in Section A.5
- Start the Subnet Manager as described in Section A.7
- Configure the DHCP server as described in Section A.6 and start it
- Configure and start at least one of the services iSCSI Target (see Section A.12) and TFTP (see Section A.8)

A.10.2 Starting Boot

Boot the client machine and enter BIOS setup to configure gPXE to be the first on the boot device priority list – see Section A.9.

If gPXE was selected through BIOS setup, the client will boot from BoIB. The client will display BoIB attributes and wait for IB port configuration by the subnet manager.

```
gPXE starting boot

Mellanox Boot over IB for InfiniHost III Ex (ver. 1.0.0)
Loading via IB Port 2
Waiting for Infiniband link-up....ok
```

After configuring the IB port, the client attempts connecting to the DHCP server to obtain the source location of the kernel/OS to boot from.

```
gPXE 0.9.3 -- Open Source Boot Firmware -- http://etherboot.org
Features: TFTP iSCSI AoE PXE PXEXT
net0: 00550401:fe800000:00000000:0002c902:00231392 on PCI05:00.0 (ope
:0 RX:0 RXE:0
DHCP (net0 00550401:fe800000:00000000:0002c902:00231392)... ok
net0: 11.4.3.130/255.255.255.0
```

A.11 Diskless Machines

Mellanox Boot over IB supports booting diskless machines. To enable using an IB driver, the (remote) kernel or `initrd` image must include and be configured to load the IB driver, including IPoIB.

This can be achieved either by compiling the HCA driver into the kernel, or by adding the device driver module into the `initrd` image and loading it.

The IB driver requires loading the following modules in the specified order (see Section A.11.1 for an example):

- ib_addr.ko
- ib_core.ko
- ib_mad.ko
- ib_sa.ko
- ib_cm.ko
- ib_uverbs.ko
- ib_ucm.ko
- ib_umad.ko
- iw_cm.ko
- rdma_cm.ko
- rdma_ucm.ko
- mlx4_core.ko
- mlx4_ib.ko
- ib_mthca.ko
- ib_ipoib.ko

A.11.1 Example: Adding an IB Driver to initrd

Prerequisites

1. The BoIB image is already programmed on the HCA card.
2. The DHCP server is installed and configured as described in Section 3.2.1, “IPoIB Configuration Based on DHCP” and Section A.6.1, “Configuring the DHCP Server”, and connected to the client machine.
3. An `initrd` file.
4. To add an IB driver into `initrd`, you need to copy the IB modules to the diskless image. Your machine needs to be pre-installed with a Mellanox OFED for Linux ISO image that is appropriate for the kernel version the diskless image will run.

Note: The remainder of this section assumes that Mellanox OFED has been installed on your machine. For installation details, please refer to Chapter 2, “Installation”.

Adding the IB Driver to the initrd File

Warning! The following procedure modifies critical files used in the boot procedure. It must be executed by users with expertise in the boot process. Improper application of this procedure may prevent the diskless machine from booting.

Step 1. Back up your current `initrd` file.

Step 2. Make a new working directory and change to it.

```
host1$ mkdir /tmp/initrd_ib
host1$ cd /tmp/initrd_ib
```

Step 3. Normally, the `initrd` image is zipped. Extract it using the following command:

```
host1$ gzip -dc <initrd image> | cpio -id
```

The initrd files should now be found under /tmp/initrd_ib

Step 4. Create a directory for the InfiniBand modules and copy them.

```
host1$ mkdir -p /tmp/initrd_ib/lib/modules/ib
host1$ cd /lib/modules/`uname -r`/updates/kernel/drivers
host1$cp infiniband/core/ib_addr.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/ib_core.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/ib_mad.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/ib_sa.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/ib_cm.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/ib_uverbs.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/ib_ucm.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/ib_umad.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/iw_cm.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/rdma_cm.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/core/rdma_ucm.ko /tmp/initrd_ib/lib/modules/ib
host1$cp net/mlx4/mlx4_core.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/hw/mlx4/mlx4_ib.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/hw/mthca/ib_mthca.ko /tmp/initrd_ib/lib/modules/ib
host1$cp infiniband/ulp/ipoib/ib_ipoib.ko /tmp/initrd_ib/lib/modules/ib
```

Step 5. IB requires loading an IPv6 module. If you do not have it in your `initrd`, please add it using the following command:

```
host1$ cp /lib/modules/`uname -r`/kernel/net/ipv6/ipv6.ko \
/tmp/initrd_ib/lib/modules
```

Step 6. To load the modules, you need the `insmod` executable. If you do not have it in your `initrd`, please add it using the following command:

```
host1$ cp /sbin/insmod /tmp/initrd_ib/sbin/
```

Step 7. If you plan to give your IB device a static IP address, then copy `ifconfig`. Otherwise, skip this step.

```
host1$ cp /sbin/ifconfig /tmp/initrd_ib/sbin
```

Step 8. If you plan to obtain an IP address for the IB device through DHCP, then you need to copy the DHCP client which was compiled specifically to support IB;
Otherwise, skip this step.

To continue with this step, DHCP client v3.1.1rc1 needs to be already installed with the patch, as described in Section 3.2.1.

Copy the DHCP client file and all the relevant files as described below.

```
host1# cp /sbin/dhclient /tmp/initrd_ib/sbin
host1# mkdir -p /tmp/initrd_ib/var/state/dhcp
host1# touch /tmp/initrd_ib/var/state/dhcp/dhclient.leases
host1# cp /sbin/dhclient-script /tmp/initrd_ib/sbin
host1# cp /bin/uname /tmp/initrd_ib/bin
host1# cp /usr/bin/expr /tmp/initrd_ib/bin
host1# cp /sbin/ifconfig /tmp/initrd_ib/bin
host1# cp /bin/hostname /tmp/initrd_ib/bin
```

Create a configuration file for the DHCP client (as described in Section 3.2.1.2) and place it under `/tmp/initrd_ib/sbin`. The following is an example of such a file (called `dclient.conf`):

dhclient.conf:

```
# The value indicates a hexadecimal number
interface "ib1" {
send dhcp-client-identifier \
20:00:55:04:01:fe:80:00:00:00:00:00:00:02:c9:02:00:23:13:92;
}
```

Step 9. Now you can add the commands for loading the copied modules into the file `init`. Edit the file `/tmp/initrd_ib/init` and add the following lines at the point you wish the IB driver to be loaded.

Warning! The order of the following commands (for loading modules) is critical.

```
echo "loading ipv6"
/sbin/insmod /lib/modules/ipv6.ko
echo "loading IB driver"
/sbin/insmod /lib/modules/ib/ib_addr.ko
/sbin/insmod /lib/modules/ib/ib_core.ko
/sbin/insmod /lib/modules/ib/ib_mad.ko
/sbin/insmod /lib/modules/ib/ib_sa.ko
/sbin/insmod /lib/modules/ib/ib_cm.ko
/sbin/insmod /lib/modules/ib/ib_uverbs.ko
/sbin/insmod /lib/modules/ib/ib_ucm.ko
/sbin/insmod /lib/modules/ib/ib_umad.ko
/sbin/insmod /lib/modules/ib/iw_cm.ko
```

```
/sbin/insmod /lib/modules/ib/rdma_cm.ko
/sbin/insmod /lib/modules/ib/rdma_ucm.ko
/sbin/insmod /lib/modules/ib/mlx4_core.ko
/sbin/insmod /lib/modules/ib/mlx4_ib.ko
/sbin/insmod /lib/modules/ib/ib_mthca.ko
/sbin/insmod /lib/modules/ib/ib_ipoib.ko
```

Step 10. Now you can assign an IP address to your IB device by adding a call to `ifconfig` or to the DHCP client in the `init` file after loading the modules. If you wish to use the DHCP client, then you need to add a call to the DHCP client in the `init` file after loading the IB modules. For example:

```
/sbin/dhclient -cf /sbin/dhclient.conf ib1
```

Step 11. Save the `init` file.

Step 12. Close `initrd`.

```
host1$ cd /tmp/initrd_ib
host1$ find ./ | cpio -H newc -o > /tmp/new_initrd_ib.img
host1$ gzip /tmp/new_init_ib.img
```

Step 13. At this stage, the modified `initrd` (including the IB driver) is ready and located at `/tmp/new_init_ib.img.gz`. Copy it to the original `initrd` location and rename it properly.

A.12 iSCSI Boot

Mellanox Boot over IB enables an iSCSI-boot of an OS located on a remote iSCSI Target. It has a built-in iSCSI Initiator which can connect to the remote iSCSI Target and load from it the kernel and `initrd`. There are two instances of connection to the remote iSCSI Target: the first is for getting the kernel and `intird` via BoIB, and the second is for loading other parts of the OS via `initrd`.

Note: Linux distributions such as SuSE Linux Enterprise Server 10 SP1 and Red Hat Enterprise Linux 5.1 can be directly installed on an iSCSI target. At the end of this direct installation, initrd is capable to continue loading other parts of the OS on the iSCSI target. (Other distributions may also be suitable for direct installation on iSCSI targets.)

If you choose to continue loading the OS (after boot) through the HCA device driver, please verify that the initrd image includes the HCA driver as described in Section A.11.

A.12.1 Configuring an iSCSI Target

Prerequisites

Step 1. Make sure that an iSCSI Target is installed on your server side.

Tip You can download and install an iSCSI Target from the following location: http://sourceforge.net/project/showfiles.php?group_id=108475&package_id=117141

Step 2. Dedicate a partition on your iSCSI Target on which you will later install the operating system

Step 3. Configure your iSCSI Target to work with the partition you dedicated. If, for example, you choose partition /dev/sda5, then edit the iSCSI Target cofiguration file `/etc/ietd.conf` to include the following line under the iSCSI Target iqn line:

```
Lun 0 Path=/dev/sda5,Type=fileio
```

Tip The following is an example of an iSCSI Target iqn line:
`Target iqn.2007-08.7.3.4.10:iscsiboot`

Step 4. Start your iSCSI Target.

Example:

```
host1# /etc/init.d/iscsitarget start
```

Configuring the DHCP Server to Boot From an iSCSI Target

Configure DHCP as described in Section A.6.1, “Configuring the DHCP Server”.

Edit your DHCP configuration file (`/etc/dhcpd.conf`) and add the following lines for the machine(s) you wish to boot from the iSCSI Target:

```
Filename "";
option root-path "iscsi:iscsi_target_ip::::iscsi_target_iqn";
```

The following is an example for configuring an IB device to boot from an iSCSI Target:

```
host  host1{
filename "";
option  dhcp-client-identifier = \
fe:00:55:00:41:fe:80:00:00:00:00:00:00:00:02:c9:03:00:00:0d:41;
option root-path "iscsi:11.4.3.7::::iqn.2007-08.7.3.4.10:iscsiboot";
}
```

A.12.2 iSCSI Boot Example of SLES 10 SP1 OS

This section provides an example of installing the SLES 10 SP1 operating system on an iSCI target and booting from a diskless machine via BoIB. Note that the procedure described below assumes the following:

- The client’s LAN card is recognized during installation
- The iSCSI target can be connected to the client via LAN and InfiniBand

Prerequisites

See Section A.10.1 on page 117.

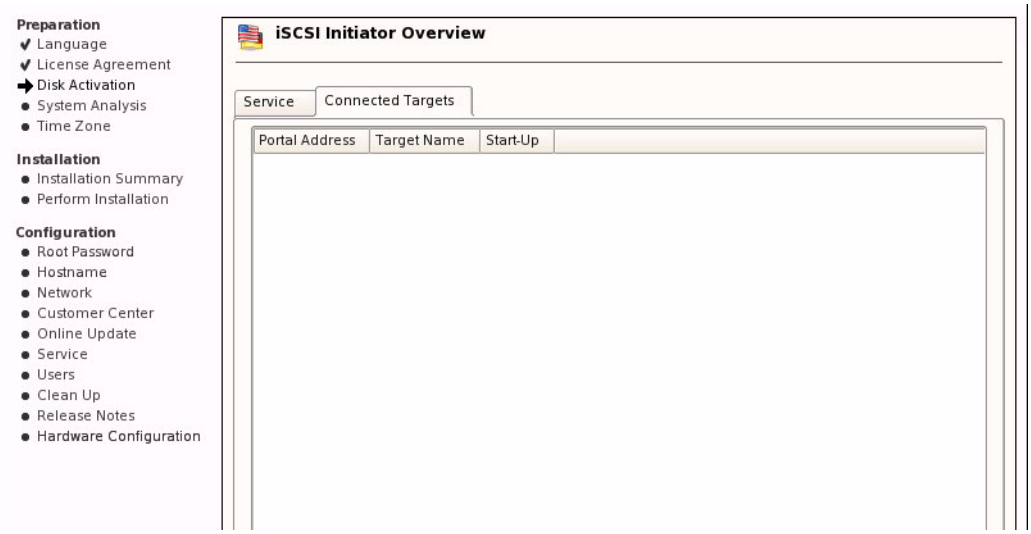
Warning! The following procedure modifies critical files used in the boot procedure. It must be executed by users with expertise in the boot process. Improper application of this procedure may prevent the diskless machine from booting.

Procedure

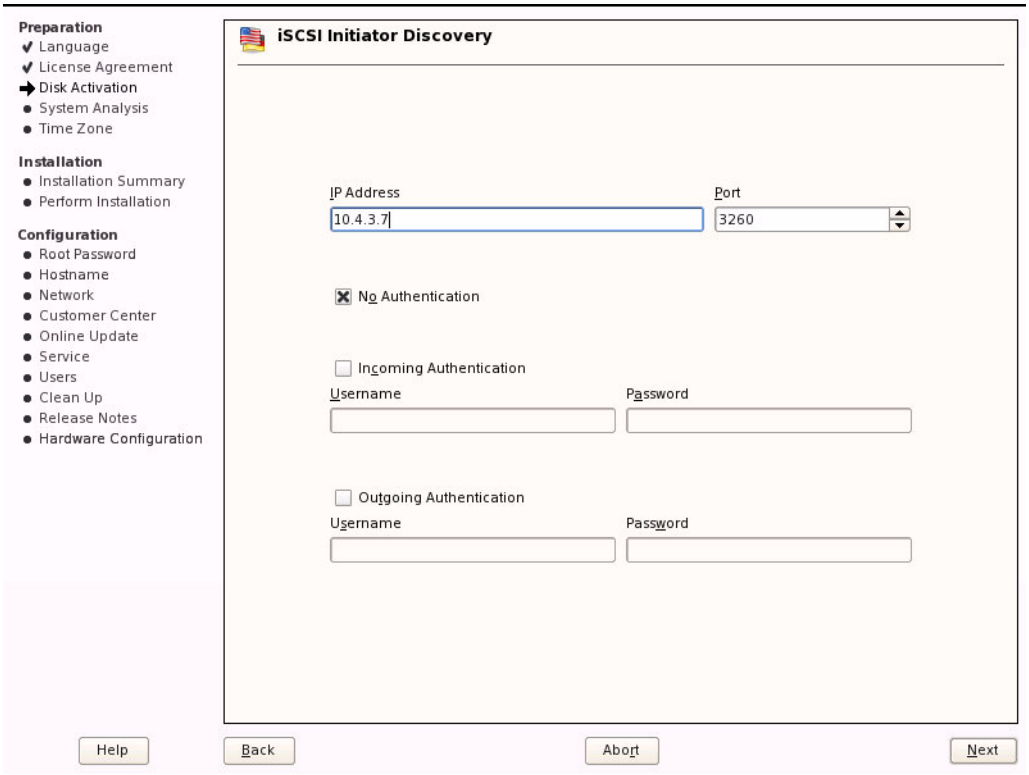
Step 1. Load the SLES 10 SP1 installation disk and enter the following parameters as boot options:

```
netsetup=1  WithISCSI=1
```

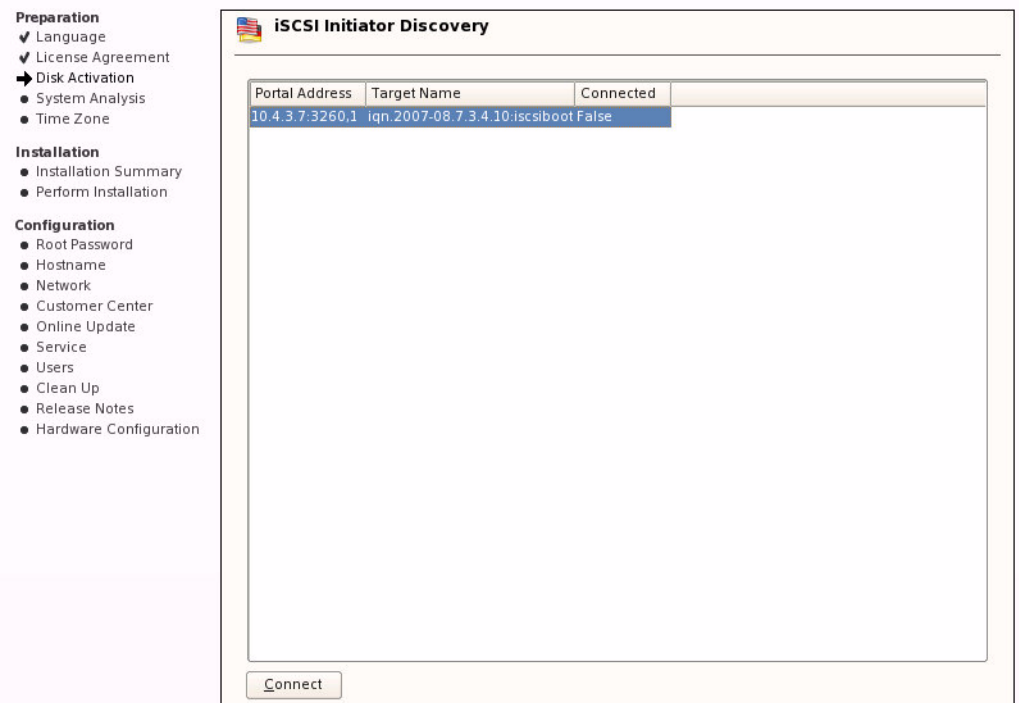
Step 2. Continue with the procedure as instructed by the installation program until the "iSCSI Initiator Overview" window appears.



Step 3. Click the Add tab in the iSCSI Initiator Overview window. An iSCSI Initiator Discrovery window will pop up. Enter the IP Address of your iSCSI target and click Next.

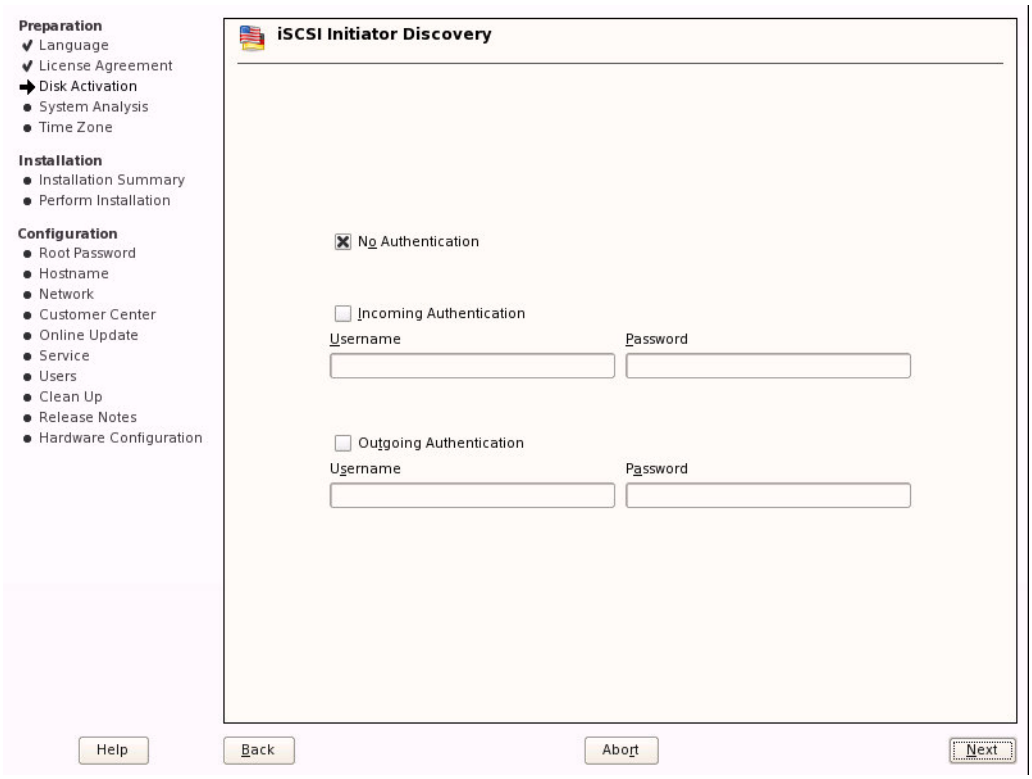


Step 4. Details of the discovered iSCSI target(s) will be displayed in the iSCSI Initiator Discrovery window. Select the target that you wish to connect to and click Connect.

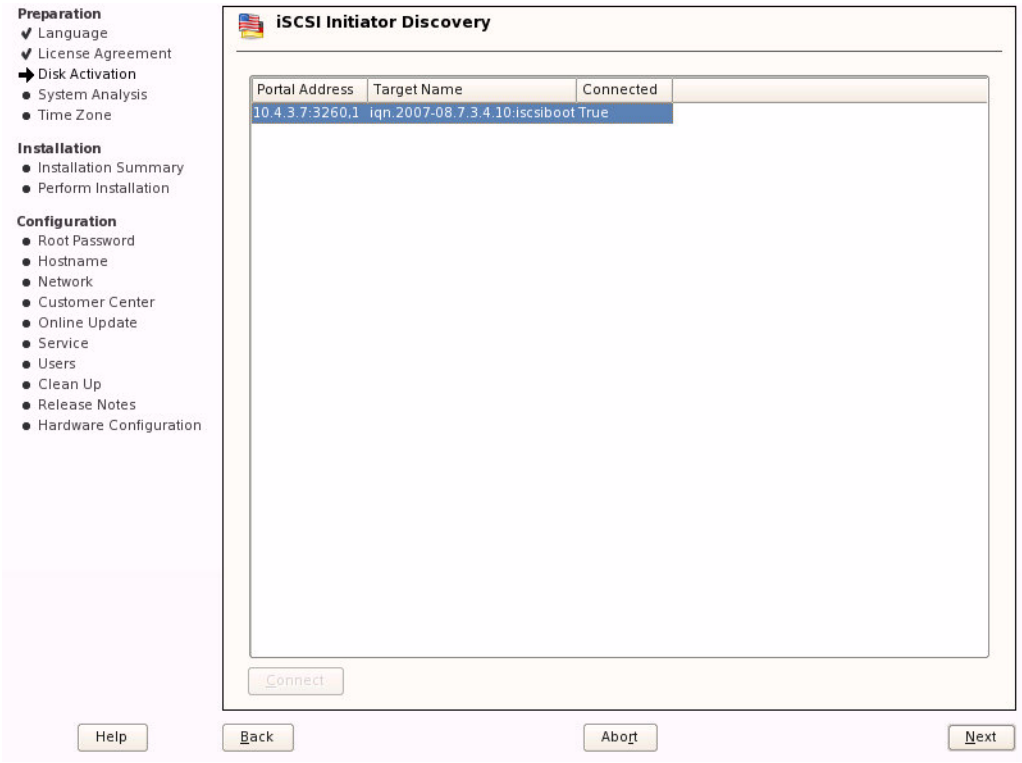


Tip If no iSCSI target was recognized, then either the target was not properly installed or no connection was found between the client and the iSCSI target. Open a shell to ping the iSCSI target (you can use CTRL-ALT-F2) and verify that the target is or is not accessible. To return to the (graphical) installation screen, press CTRL-ALT-F7.

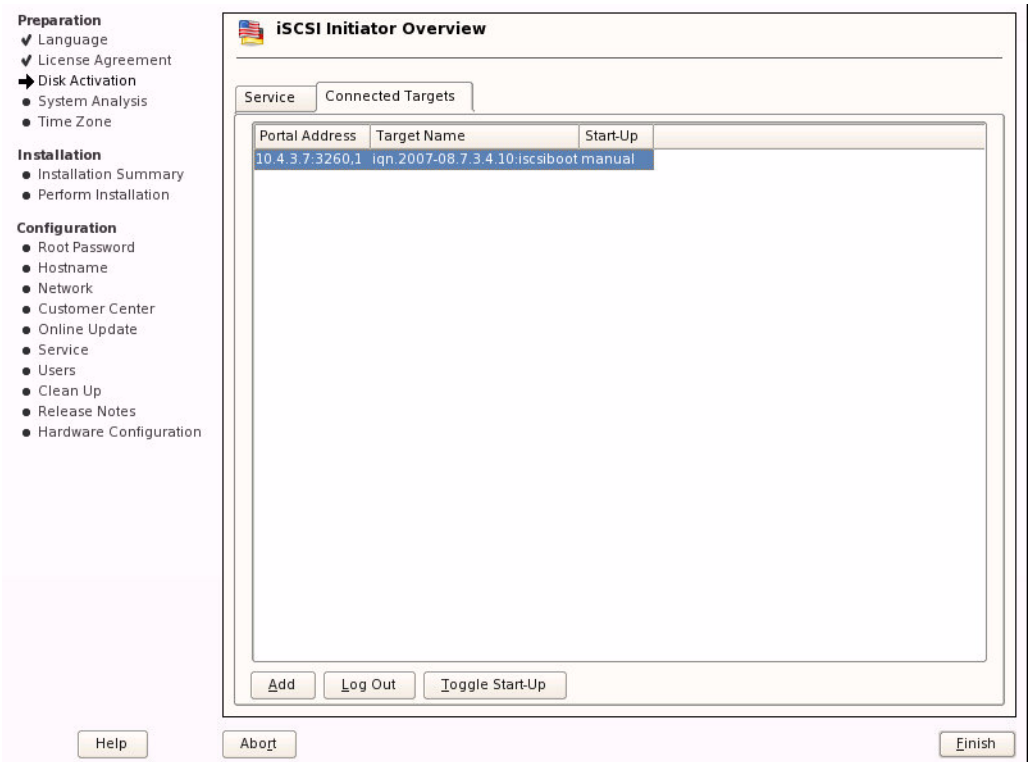
Step 5. The iSCSI Initiator Discovery window will now request authentication to access the iSCSI target. Click Next to continue without authentication unless authentication is required.



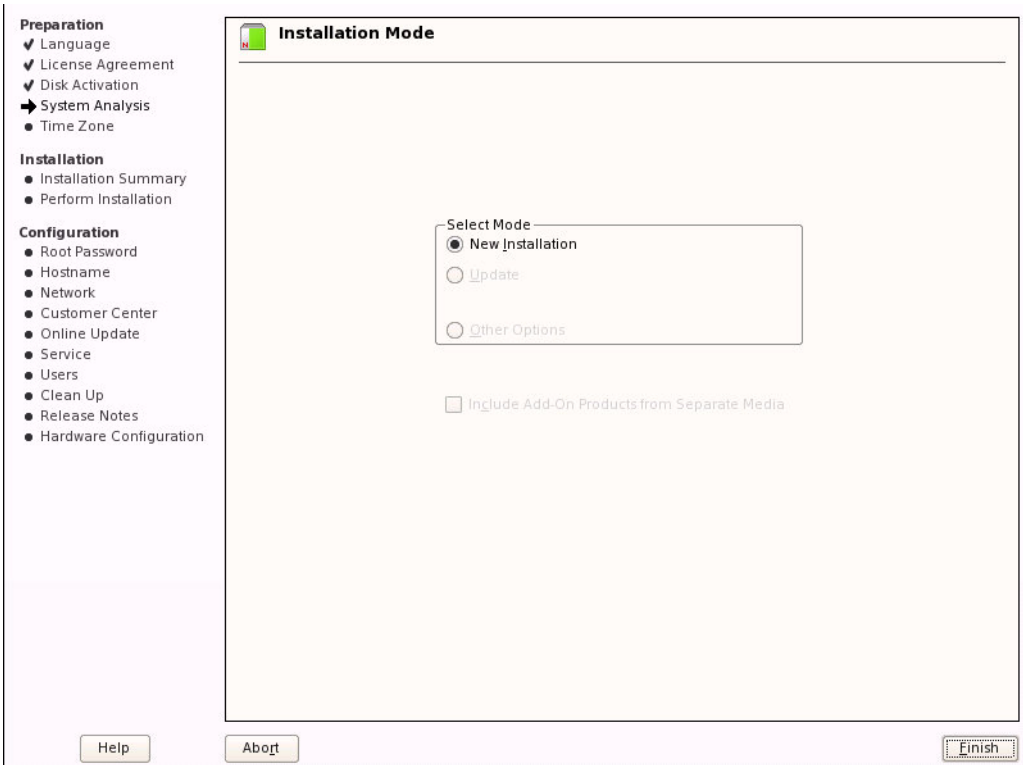
Step 6. The iSCSI Initiator Discovery window will show the iSCSI target that got connected to. Note that the Connected column must indicate True for this target. Click Next. (See figure below.)



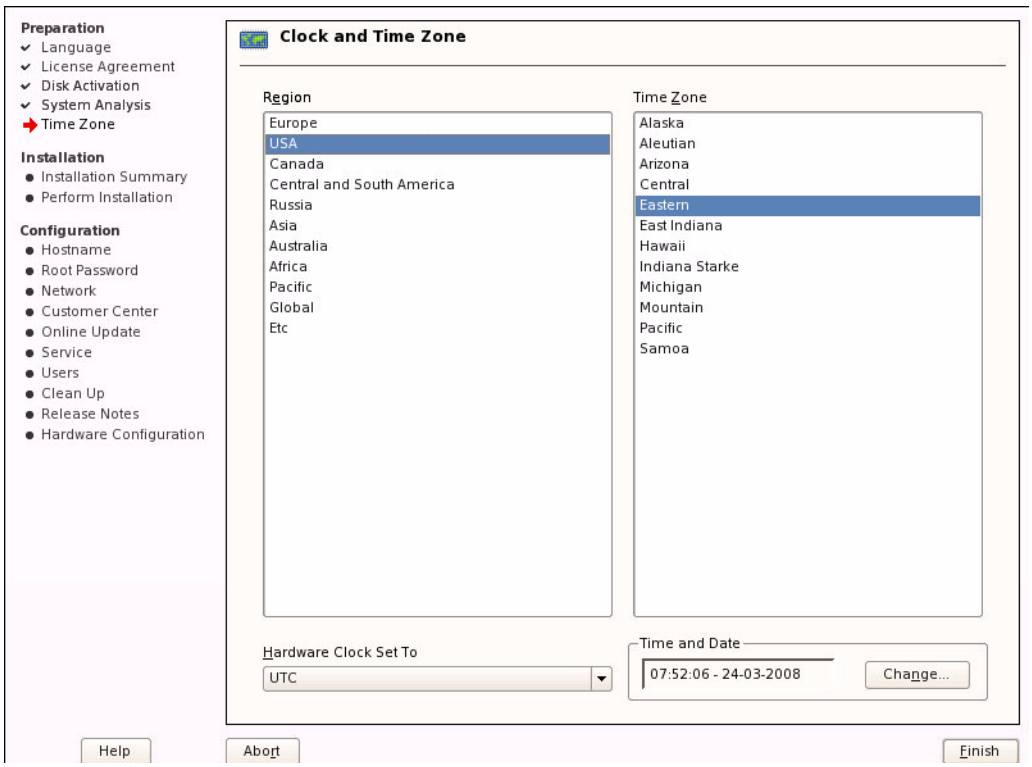
Step 7. The iSCSI Initiator Overview window will pop up. Click Toggle Start-Up to change start up from manual to automatic. Click Finish.



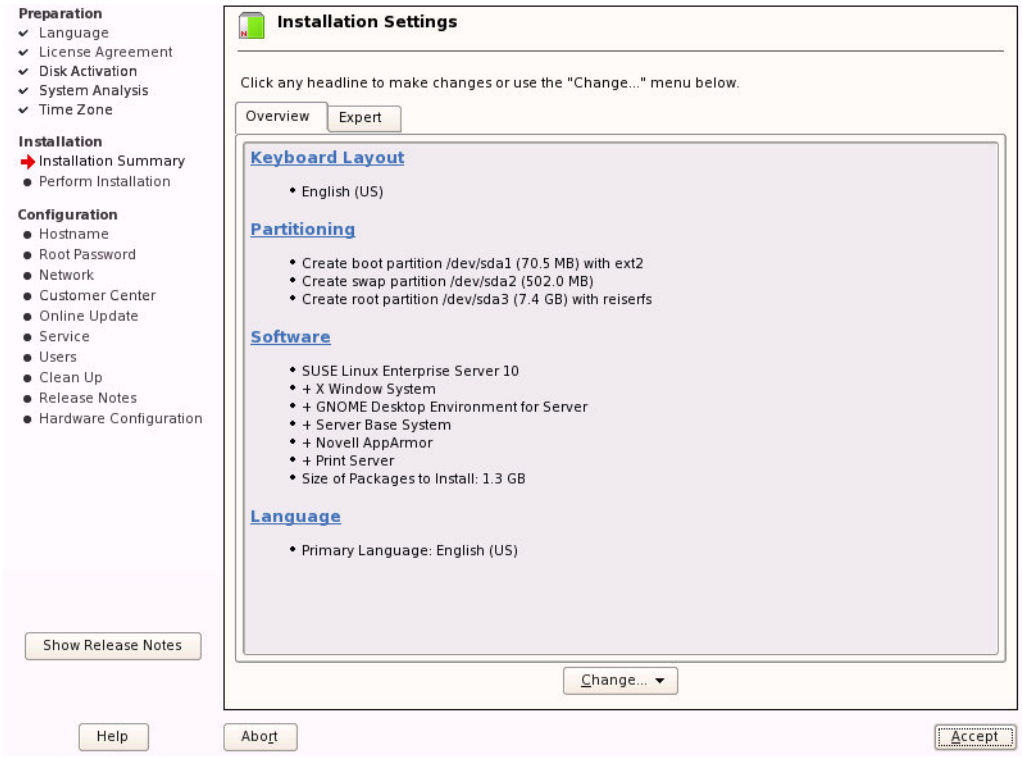
Step 8. Select New Intallation then click Finish in the Installation Mode window.



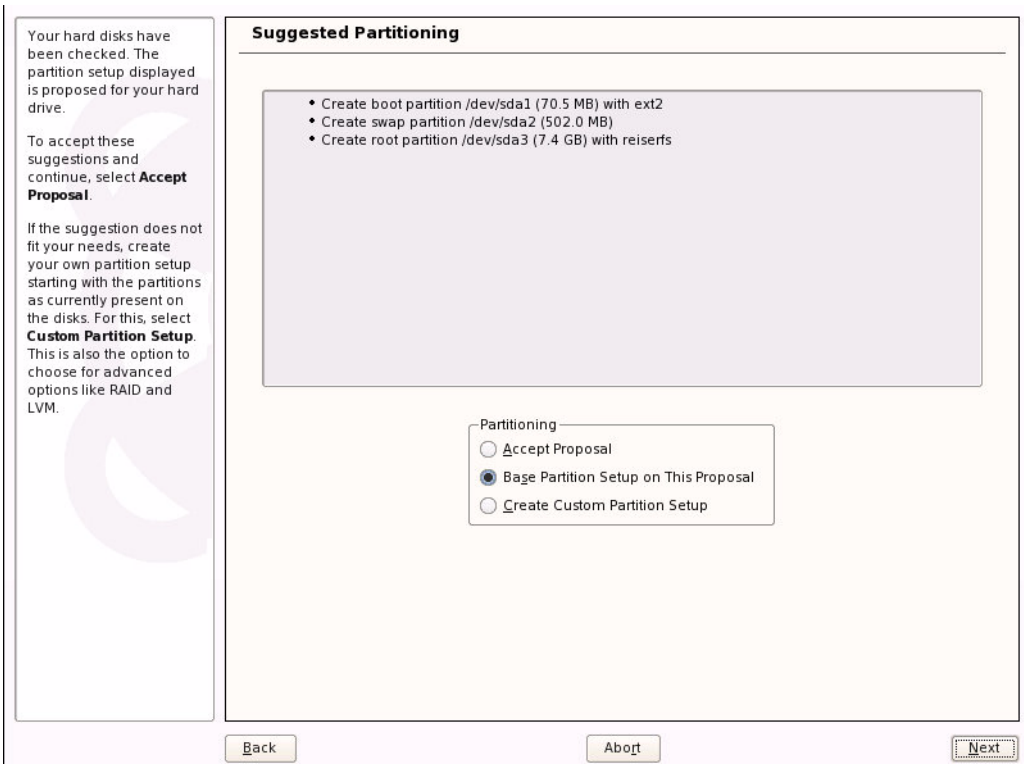
Step 9. Select the appropriate Region and Time Zone in the Clock and Time Zone window, then click Finish.



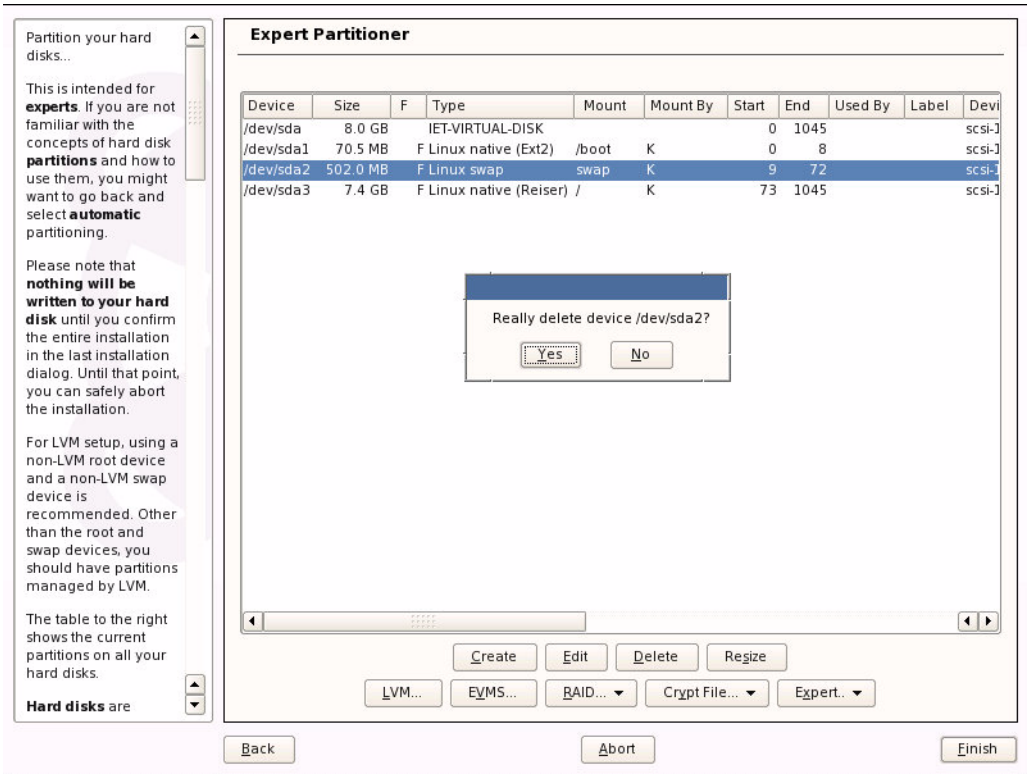
Step 10. In the Installation Settings window, click Partitioning to get the Suggested Partitioning window.



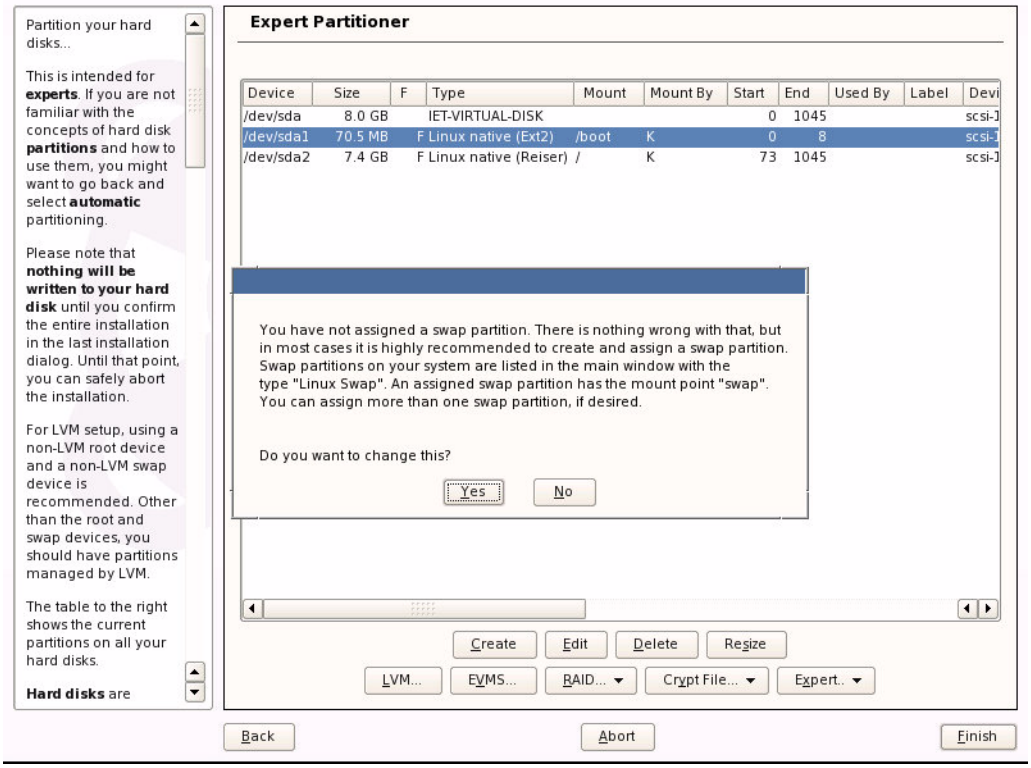
Step 11. Select Base Partition Setup on This Proposal then click Next.



Step 12. In the Expert Partitioner window, select from the IET-VIRTUAL-DISK device the row that has its Mount column indicating 'swap', then click Delete. Confirm the delete operation and click Finish.

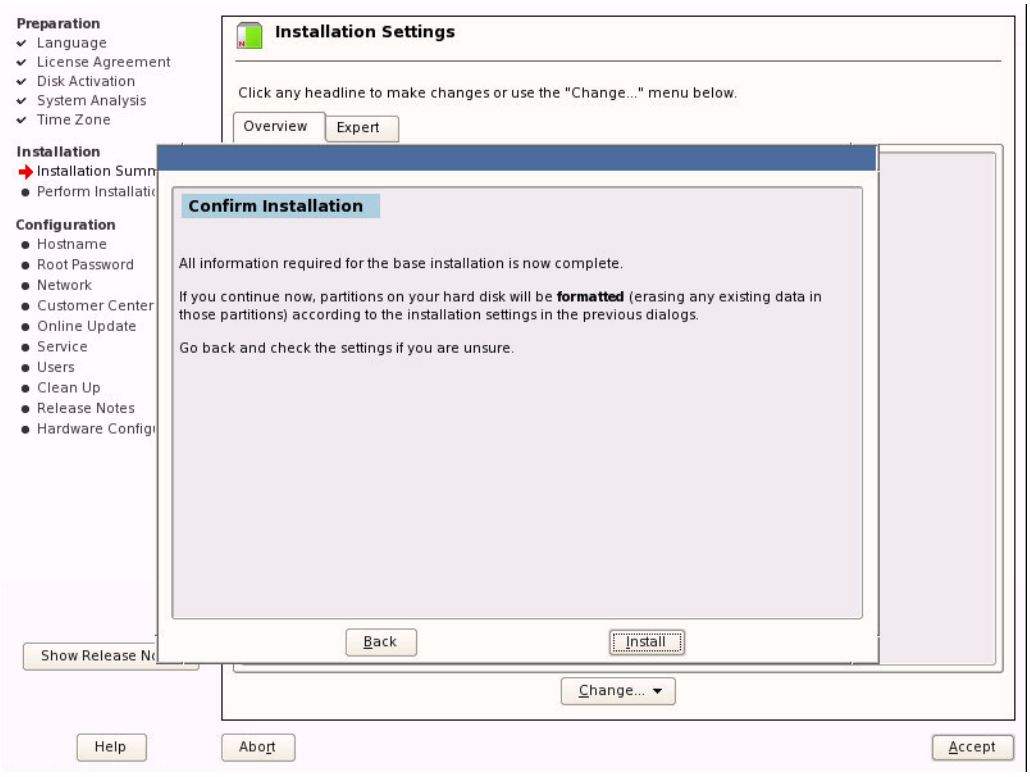


Step 13. In the pop-up window click No to approve deleting the swap partition. You will be returned to Installation Settings window. (See image below.)



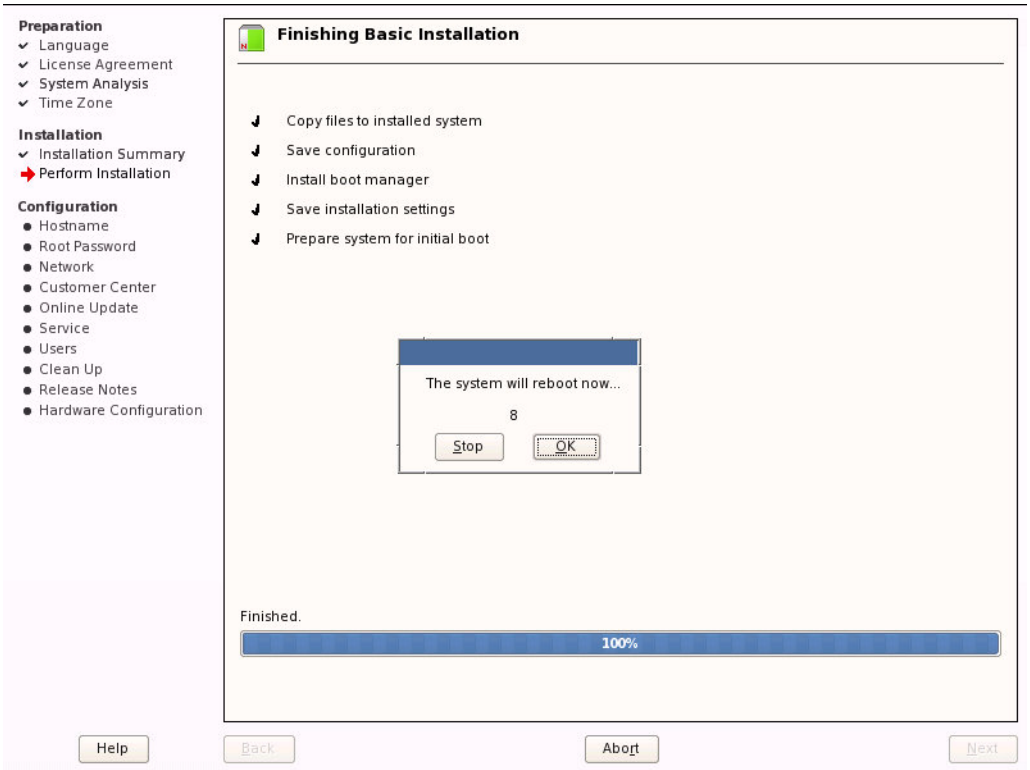
Step 14. If you wish to change additional settings, click the appropriate item and perform the changes, and click Accept when done.

Step 15. In the Confirm Installation window, click Install to start the installation. (See image below.)

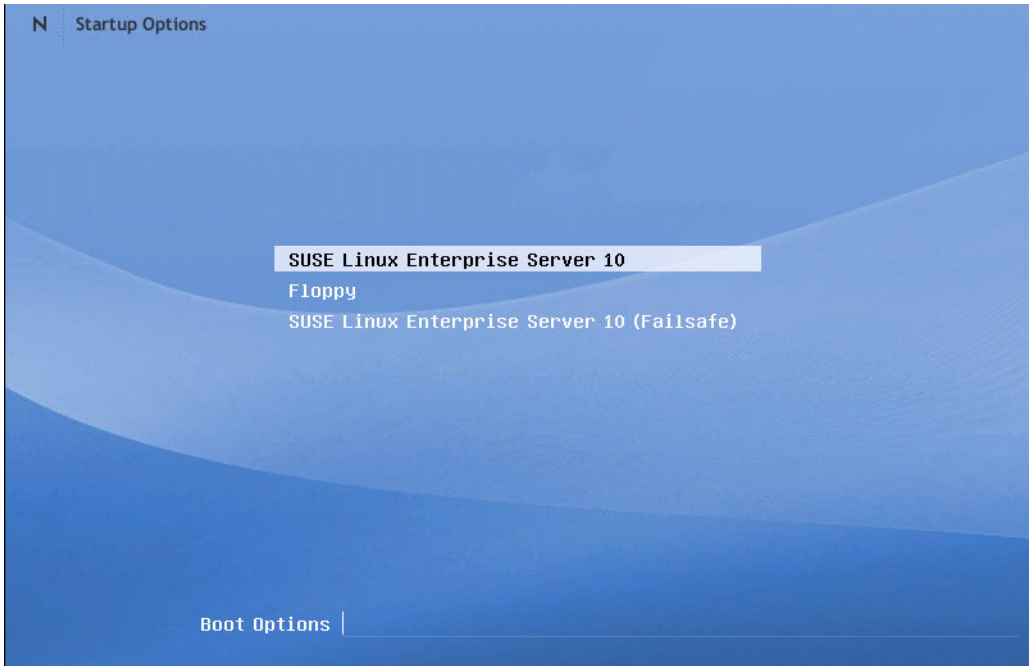


Step 16. At the end of the file copying stage, the Finishing Basic Installation window will pop up and ask for confirming a reboot. You can click OK to skip count-down. (See image below.)

Note: Assuming that the machine has been correctly configured to boot from BoIB via its connection to the iSCSI target, make sure that gPXE has the highest priority in the BIOS boot sequence.



Step 17. Once the boot is complete, the Startup Options window will pop up. Select SUSE Linux Enterprise Server 10 then press Enter.



Step 18. The Hostname and Domain Name window will pop up. Continue configuring your machine until the operating system is up, then you can start running the machine in normal operation mode.

Step 19. (Optional) If you wish to have the second instance of connecting to the iSCSI Target go through the IB driver, copy the `initrd` file under `/boot` to a new location, add the IB driver into it after the load commands of the iSCSI Initiator modules, and continue as described in Section A.11 on page 118.

Warning! Pay extra care when changing `initrd` as any mistake may prevent the client machine from booting. It is recommended to have a back-up iSCSI Initiator on a machine other than the client you are working with, to allow for debug in case `initrd` gets corrupted.

In addition, edit the `init` file (that is in the `initrd` zip) and look for the following string

```
if [ "$iSCSI_TARGET_IPADDR" ] ; then
  iscsiserver="$iSCSI_TARGET_IPADDR"
fi
```

Now add before the string the following line:

```
iSCSI_TARGET_IPADDR=<IB IP Address of iSCSI Target>
```

Example:

```
iSCSI_TARGET_IPADDR=11.4.3.7
```

Appendix B: Performance Troubleshooting

B.1 PCI Express Performance Troubleshooting

For the best performance on the PCI Express interface, the adapter card should be installed in an x8 slot with the following BIOS configuration parameters:

- Max_Read_Req, the maximum read request size, is 512 or higher
- MaxPayloadSize, the maximum payload size, is 128 or higher

Note: A Max_Read_Req of 128 and/or installing the card in an x4 slot will significantly limit bandwidth.

To obtain the current setting for Max_Read_Req, enter:

```
setpci -d "15b3:" 68.w
```

If the output is neither 2000 nor 2020, then a BIOS update is needed.

To obtain the PCI Express slot (link) width and speed, enter:

```
setpci -d "15b3:" 72
```

1. If the output is neither 81 nor 82 card, then the card is NOT installed in an x8 PCI Express slot.
2. The least significant digit indicates the link speed:
   - 1 for PCI Express Gen 1 (2.5 GT/s)
   - 2 for PCI Express Gen 2 (5 GT/s)

Note: If you are running InfiniBand at QDR (40Gb/s 4X IB ports), you must run PCI Express Gen 2.

B.2 InfiniBand Performance Troubleshooting

InfiniBand (IB) performance depends on the health of IB link(s) and on the IB card type. IB link speed (10Gb/s or SDR, 20Gb/s or DDR, 40Gb/s or QDR) also affects performance.

Note: A latency sensitive application should take into account that each switch on the path adds ~200nsec at SDR, and 150nsec for DDR.

1. To check the IB link speed, enter:

   ```
   ibstat
   ```

   Check the value indicated after the "Rate:" string: 10 indicates SDR, 20 indicates DDR, and 40 indicates QDR.

2. Check that the link has NO symbol errors since these errors result in the re-transmission of packets, and therefore in bandwidth loss. This check should be conducted for each port after the driver is loaded. To check for symbol errors, enter:

   ```
   cat /sys/class/infiniband/mthca0/ports/1/counters/symbol_error
   ```

   The command above is performed on Port 1 of the module mthca0. The output value should be 0 if no symbol errors were recorded.

3. Bandwidth is expected to vary between systems. It heavily depends on the chipset, memory, and CPU. Nevertheless, the full-wire speed should be achieved by the host.
   - With IB @ SDR, the expected unidirectional full-wire speed bandwidth is ~900MB/sec.
   - With IB @ DDR and PCI Express Gen 1, the expected unidirectional full-wire speed bandwidth is ~1400MB/sec. (See Section B.1.)
   - With IB @ DDR and PCI Express Gen 2, the expected unidirectional full-wire speed bandwidth is ~1800MB/sec. (See Section B.1.)
   - With IB @ QDR and PCI Express Gen 2, the expected unidirectional full-wire speed bandwidth is ~3000MB/sec. (See Section B.1.)

   To check the adapter's maximum bandwidth, use the `ib_write_bw` utility.

   To check the adapter's latency, use the `ib_write_lat` utility.

   Note: The utilities `ib_write_bw` and `ib_write_lat` are installed as part of Mellanox OFED.

Appendix C: ULP Performance Tuning

C.1 IPoIB Performance Tuning

This section provides tuning guidelines of TCP stack configuration parameters in order to boost IPoIB and IPoIB-CM performance.

Without tuning the parameters, the default Linux configuration may significantly limit the total available bandwidth below the actual capabilities of the adapter card. The parameter settings described below will increase the ability of Linux to transmit and receive data.

- Generally, if you increase the MTU (maximum transmission unit in bytes) you get better performance. The following MTUs are suggested (use **`ifconfig`** to modify the MTU):
  - IPoIB 2044 bytes
  - IPoIB-CM 64K bytes

- Copy the following lines to (a new file) `ipoib_perf.conf`:

```
net.ipv4.tcp_rmem = 4096 87380 16777216
net.ipv4.tcp_wmem = 4096 65536 16777216
net.core.rmem_max = 16777216
net.core.wmem_max = 16777216
```

  Load the file using the following command:

```
sysctl -p <path>/ipoib_perf.conf
```

Note: The parameter settings above were tested using several benchmarks and yielded performance improvements. However, some kernels may require different parameter values.

C.2 MPI Performance Tuning

To optimize bandwidth and message rate running over MVAPICH, you can set tuning paramters either using the command line, or in the configuration file:
`/usr/mpi/<compiler>/mvapich-<mvapich-ver>/etc/mvapich.conf`

Tuning Parameters in Configuration File

Edit the `mvapich.conf` file with the following lines:

```
VIADEV_USE_COALESCE=1
VIADEV_COALESCE_THRESHOLD_SQ=1
VIADEV_PROGRESS_THRESHOLD=2
```

Tuning Parameters via Command Line

The following command tunes MVAPICH parameters:

```
host1$ /usr/mpi/gcc/mvapich-<mvapich-ver>/bin/mpirun_rsh -np 2 \
-hostfile /home/<username>/cluster \
VIADEV_USE_COALESCE=1 VIADEV_COALESCE_THRESHOLD_SQ=1 \
VIADEV_PROGRESS_THRESHOLD=2 \
/usr/mpi/gcc/mvapich-<mvapich-ver>/tests/osu_benchmarks-<osu-ver>/osu_bw
```

The example assumes the following:

- A cluster of at least two nodes. Example: host1, host2
- A machine file that includes the list of machines. Example:

```
host1$ cat /home/<username>/cluster
host1
host2
host1$
```

Glossary

The following is a list of concepts and terms related to InfiniBand in general and to Subnet Managers in particular. It is included here for ease of reference, but the main reference remains the *InfiniBand Architecture Specification*.

Channel Adapter (CA)

An IB device that terminates an IB link and executes transport functions. This may be an HCA (Host CA) or a TCA (Target CA).

IB Devices

Integrated circuit implementing InfiniBand compliant communication.

IB Cluster/Fabric/Subnet

A set of IB devices connected by IB cables.

In-Band

A term assigned to administration activities traversing the IB connectivity only.

LID

An address assigned to a port (data sink or source point) by the Subnet Manager, unique within the subnet, used for directing packets within the subnet.

Local Device/Node/System

The IB Host Channel Adapter (HCA) Card installed on the machine running IBDIAG tools.

Local Port

The IB port of the HCA through which IBDIAG tools connect to the IB fabric.

Master Subnet Manager

The Subnet Manager that is authoritative, that has the reference configuration information for the subnet. See Subnet Manager.

Multicast Forwarding Tables

A table that exists in every switch providing the list of ports to forward received multicast packet. The table is organized by MLID.

Standby Subnet Manager

A Subnet Manager that is currently quiescent, and not in the role of a Master Subnet Manager, by agency of the master SM. See Subnet Manager.

Subnet Administrator (SA)

An application (normally part of the Subnet Manager) that implements the interface for querying and manipulating subnet management data.

Subnet Manager (SM)

One of several entities involved in the configuration and control of the subnet.

Unicast Linear Forwarding Tables (LFT)

A table that exists in every switch providing the port through which packets should be sent to each LID.