Red Hat Reference Architecture Series

Red Hat Enterprise Linux 6 - High Performance Network with MRG - MRG Messaging: Throughput & Latency 1-GigE, 10-GigE and 10 Gb InfiniBand™

Red Hat Enterprise MRG – MRG Messaging 1.3
Red Hat® Enterprise Linux® 6.0
Intel Westmere 12 CPU 24 GB
Intel 1 GigE / Mellanox 10 GigE / Mellanox InfiniBand

Version 2.0

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Goals & Executive Summary

High Performance Network Add-On

Red Hat Enterprise Linux 6 includes Red Hat's High Performance Network Add-On. This Add-on delivers remote directory memory access over converged Ethernet (RoCE) for those times when low network latency and high capacity are important. Because RoCE bypasses system and kernel calls to place data directly into remote system memory with less CPU overhead, the High Performance Networking Add-On is ideal for high-speed data processing applications that require low latency, for speeding up cluster locking, or for scaling up applications on distributed systems without investing in specialized networking technologies.

MRG is a next-generation IT infrastructure that makes enterprise computing 100-fold faster, defines new levels of interoperability and gives customers competitive advantage by running applications and transactions with greater performance and reliability. Red Hat Enterprise MRG integrates Messaging, Realtime, and Grid technologies. Messaging is the backbone of enterprise and high-performance computing, SOA (Service-oriented architecture) deployments, and platform services. MRG provides enterprise messaging technology that delivers:

- Unprecedented interoperability through the implementation of AMQP (Advanced Message Queuing Protocol), the industry's first open messaging standard. The solution is cross-language, cross-platform, multi-vendor, spans hardware and software, and extends down to the wire level. Red Hat is a founding member of the AMQP working group, which develops the AMQP standard.
- Linux-specific optimizations to achieve optimal performance on Red Hat Enterprise Linux and MRG Realtime. It can also be deployed on non-Linux platforms such as Windows and Solaris without the full performance and quality of service benefits that Red Hat Enterprise Linux provides.
- Support for most major development languages.

This paper generates performance numbers for MRG Messaging under the Red Hat Enterprise Linux 6 (RHEL) operating system using various interconnects and supported protocols include RoCE.

- Performance numbers are useful to raise interest in AMQP and MRG Messaging technology when deployed on Red Hat Enterprise Linux.
- This report compares hardware network options to help in deployment and technology selection.
- This report makes no attempt to plot the maximum throughput of MRG, but rather a controlled comparison in a minimal network configuration.

1 Goals

- Generate MRG Messaging performance numbers, latency and throughput, with various interconnects and supported protocols.
- Evaluate the High Performance Network Add-On in Red Hat Enterprise Linux 6 w/ RDMA over Converged Ethernet (RoCE).
- Provide tuning and optimization recommendations for MRG Messaging.

2 Executive Summary

This study measured the throughput and 2-hop fully reliable latency of MRG Messaging V1.1 (using AMQP 0-10 protocol) using 8 to 16384-byte packets running on RHEL 6.0. The results provided were achieved with the testbed described in **Section 4**. It is quite possible higher throughput could be achieved with multiple drivers and multiple instances of adapters.

Three physical interconnects were used. A single protocol, TCP, was used with the 1-GigE. Two protocols were used with the 10-GigE interconnects and InfiniBand (IB) interconnect. Internet Protocol over InfiniBand (IPoIB) allows users to take partial advantage of IB's latency and throughput using pervasive Internet Protocols (IP). Using the Remote Direct Memory Access (RDMA) protocol allows users to take full advantage of the latency and throughput of the IB interconnect however, the cost is loss of the IP application and programming interfaces.

Latency results show that faster interconnects will yield lower latencies. Also show is Mellonox 10Gig-E and Mellonox 10Gbit-IB provided the shortest latency. The new Mellonox 10Gig-E w/ RDMA over Converged Ethernet (RoCE) had best with averaged readings at 68 microseconds using 10Ge. Mellonox's IB (connectX2) had latencies just over 70 microseconds. The 10-GigE latencies increased more with transfer size but had results just over 100 microseconds. The 1-GigE best average was 130 microseconds.

For throughput, the faster interconnects prove their worth with larger transfer sizes, the results for smaller transfers had much smaller variances. While 10 GigE hardware was always the best performer, which of the two tested IB protocols to achieve the best throughput changed with the transfer size. For 64-byte transfers, 10Gig-E performed best with over 73.5 MB/s recorded, followed by 1-gigE (72.67 MB/s), RDMA (64.7 MB/s), 10-GigE RDMA (63 MB), and IB RDMA (59.23 MB/s). Using 256-byte transfers, 10-GigE and 1-GigE wins with 243 MB/s, closely trailed by IPoIB (234 MB/s), 10-GigE RDMA (224), IB RDMA (176.8). With a 1024-byte transfer size, 10-GigE ranks first at 815 MB/s, 10-GigE is close with 679 MB/s, then IB RDMA (333.2 MB/s), IPoIB (331.58 MB/s), and 1-GigE (201.6 MB/s) complete the sequence.

Red Hat MRG Messaging – Introduction & Architecture

1 The Basis of MRG Messaging

1.1 Advanced Message Queuing Protocol

AMQP is an open-source messaging protocol. It offers increased flexibility and interoperability across languages, operating systems, and platforms. AMQP is the first open standard for high performance enterprise messaging. More information about AMQP is available at http://www.amqp.org. The full protocol specification is available at http://jira.amqp.org/confluence/download/attachments/720900/amqp.0-10.pdf?version=1 .

1.2 Apache Qpid

Qpid is an Apache project that implements the AMQP protocol. It is a multi-platform messaging implementation that delivers transaction management, queuing, distribution, security and management. Development on MRG Messaging is also contributed back upstream to the Qpid project. More information can be found on the http://qpid.apache.org.

1.3 Red Hat Enterprise MRG Messaging

MRG Messaging is an open source messaging distribution that uses the AMQP protocol. MRG Messaging is based on Qpid, but includes persistence options, additional components, Linux kernel optimizations, and operating system services not found in the Qpid implementation. For more information refer to http://www.redhat.com/mrg.

2 How MRG Messaging Operates

MRG Messaging was designed to provide a way to build distributed applications in which programs exchange data by sending and receiving messages. A message can contain any kind of data. Middleware messaging systems allow a single application to be distributed over a network and throughout an organization without being restrained by differing operating systems, languages, or network protocols. Sending and receiving messages is simple, and MRG Messaging provides guaranteed delivery and extremely good performance.

In MRG Messaging a *message producer* is any program that sends messages. The program that receives the message is referred to as a *message consumer*. If a program both sends and receives messages it is both a message producer and a message consumer.

The *message broker* is the hub for message distribution. It receives messages from message producers and uses information stored in the message's headers to decide where to send it on to. The broker will normally attempt to send a message until it gets notification from a consumer that the message has been received.

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Within the broker are *exchanges* and *queues*. Message producers send messages to exchanges, message consumers subscribe to queues and receive messages from them.

The message headers contain *routing* information. The *routing key* is a string of text that the exchange uses to determine which queues to deliver the message to. *Message properties* can also be defined for settings such as message durability.

A *binding* defines the relationship between an exchange and a message queue. A queue must be bound to an exchange in order to receive messages from it. When an exchange receives a message from a message producer, it examines its active bindings, and routes the message to the corresponding queue. Consumers read messages from the queues to which they are subscribed. Once a message is read, it is removed from the queue and discarded.

As shown in **Figure 1**, a producer sends messages to an exchange. The exchange reads the active bindings and places the message in the appropriate queue. Consumers then retrieve messages from the queues.

Figure 1

5 Red Hat MRG Messaging (AMQP) Architecture

AMQP was born out of the frustrations in developing front- and back-office processing systems at investment banks. No existing products appeared to meet all the requirements of these investment banks.

AMQP is a binary wire protocol and well-defined set of behaviors for transmitting application messages between systems using a combination of store-and-forward, publish-and-subscribe, and other techniques. AMQP addresses the scenario where there is likely to be some economic impact if a message is lost, does not arrive in a timely manner, or is improperly processed.

The protocol is designed to be usable from different programming environments, operating systems, and hardware devices, as well as making high-performance implementations possible on various network transports including TCP, SCTP (Stream Control Transmission Protocol), and InfiniBand.

From the beginning, AMQP's design objective was to define enough MOM semantics (**Figure 2**) to meet the needs of most commercial computing systems and to do so in an efficient manner that could ultimately be embedded into the network infrastructure. It's not just for banks.

AMQP encompasses the domains of store-and-forward messaging, publish-and-subscribe messaging, and point to point. It incorporates common patterns to ease the traversal of firewalls while retaining security, and to permit network QoS. To ease adoption and migration, AMQP is also designed to encompass JMS (Java Message Service) semantics.

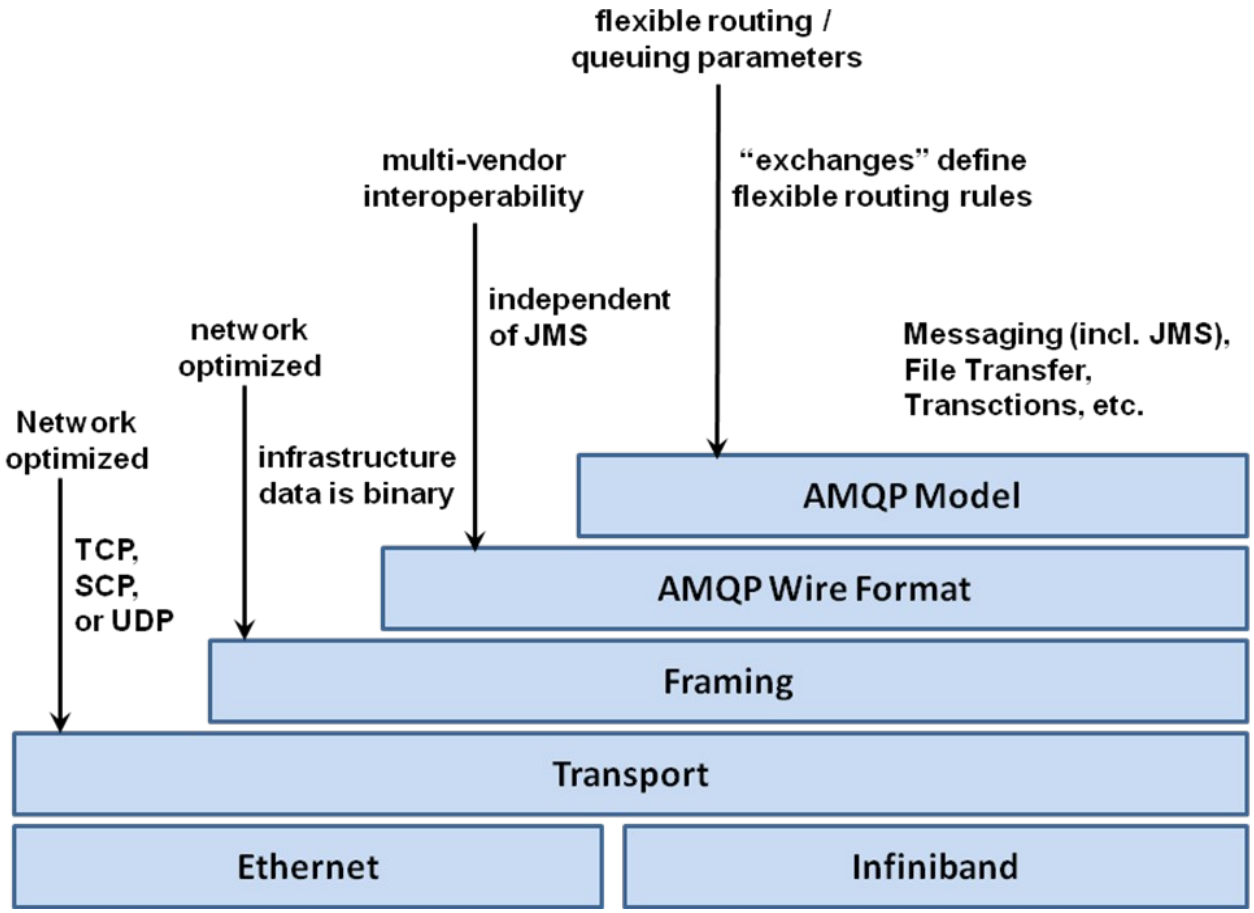


Figure 2

AMQP goes further, however, and includes additional semantics not found in JMS that members of the working group have found useful in delivering large, robust systems over the decades. Interestingly, AMQP does not itself specify the API a developer uses, though it is likely that will happen in the future.

5.1 Main Features

AMQP is split into two main areas: transport model and queuing model. AMQP is unusual in that it thoroughly specifies the semantics of the services it provides within the queuing model; since applications have a very intimate relationship with their middleware, this needs to be well defined or interoperability cannot be achieved. In this respect, AMQP semantics are more tightly defined than JMS semantics.

As stated, AMQP's transport is a binary protocol using network byte ordering. AMQP aims to be high performance and flexible, and to be hardware friendly rather than human friendly. The protocol *specification* itself, however, is written in XML so implementers can code-generate large portions of their implementations; this makes it easier for vendors to support the technology.

The transport model itself can use different underlying transports. MRG supports TCP/IP, InfiniBand RDMA, 10GigE RDMA and TSL.

5.2 Messages

Messages in AMQP are self-contained and long-lived, and their content is immutable and opaque. The content of messages is essentially unlimited in size; 4GB messages are supported just as easily as 4KB messages. Messages have headers that AMQP can read and use to help in routing.

You can liken this to a postal service: a message is the envelope, the headers are information written on the envelope and visible to the mail carrier, who may add various postmarks to the envelope to help deliver the message. The valuable content is within the envelope, hidden from and not modified by the carrier. The analogy holds quite well, except that it is possible for AMQP to make unlimited copies of the messages to deliver if required.

5.3 Queues

Queues are the core concept in AMQP. Every message *always* ends up in a queue, even if it is an in-memory private queue feeding a client directly. To extend the postal analogy, queues are mailboxes at the final destination or intermediate holding areas in the sorting office.

Queues can store messages in memory or on disk. They can search and reorder messages, and they may participate in transactions. The administrator can configure the service levels they expect from the queues with regard to latency, durability, availability, etc. These are all aspects of implementation and not defined by AMQP. This is one way commercial implementations can differentiate themselves while remaining AMQP-compliant and interoperable.

5.4 Exchanges

Exchanges are the delivery service for messages. In the postal analogy, exchanges provide sorting and delivery services. In the AMQP model, selecting a different carrier is how *different ways of delivering the message* are selected. The exchange used by a publish operation determines if the delivery will be direct or publish-and-subscribe, for example. The exchange concept is how AMQP brings together and abstracts different middleware delivery models. It is also the main extension point in the protocol.

A client chooses the exchange used to deliver each message as it is published. The exchange looks at the information in the headers of a message and selects where they should be transferred to. This is how AMQP brings the various messaging idioms together - clients can select which exchange should route their messages.

Several exchanges must be supported by a compliant AMQP implementation:

- The fanout exchange will distribute messages to every queue. Any routing information provided by the producer is ignored. See **Figure 3**.

- The direct exchange will queue a message directly at a single queue, choosing the queue on the basis of the "routing key" header in the message and matching it by name. This is how a letter carrier delivers a message to a postal address. See **Figure 4**.
- The topic exchange will copy and queue the message to all clients that have expressed an interest based on a rapid pattern match with the routing key header. You can think of the routing key as an address, but it is a more abstract concept useful to several types of routing. See **Figure 5**.
- The headers exchange will examine all the headers in a message, evaluating them against query predicates provided by interested clients using those predicates to select the final queues, copying the message as necessary.
- In addition the implementation provides an additional exchange for XML routing. This exchange allows for the routing of XML based messages using XQuery. The XML exchange has not been benchmarked in this report.

Throughout this process, exchanges never store messages, but they do retain binding parameters supplied to them by the clients using them. These bindings are the arguments to the exchange routing functions that enable the selection of one or more queues.

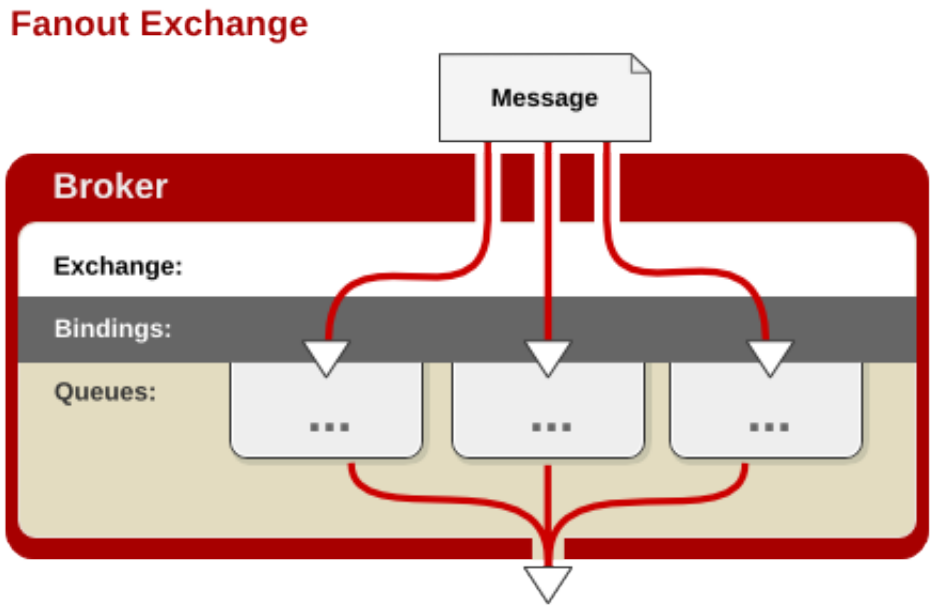


Figure 3

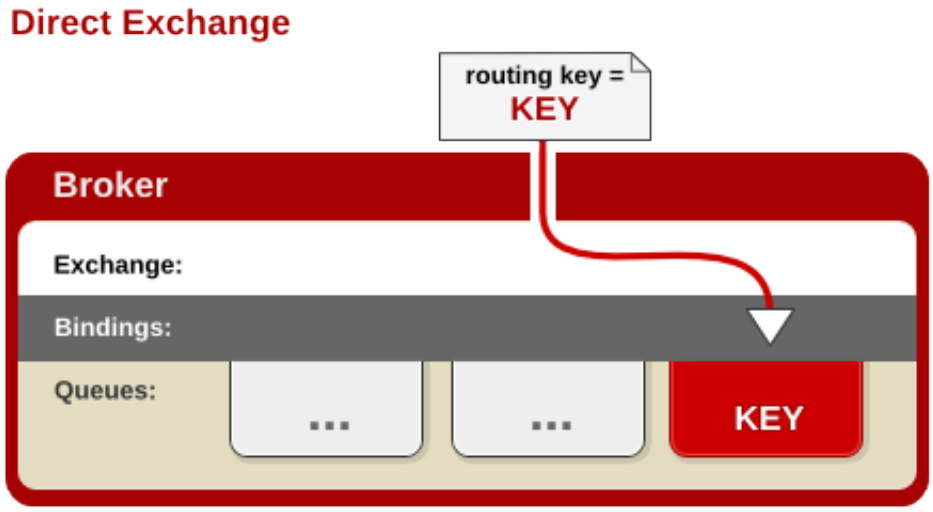


Figure 4

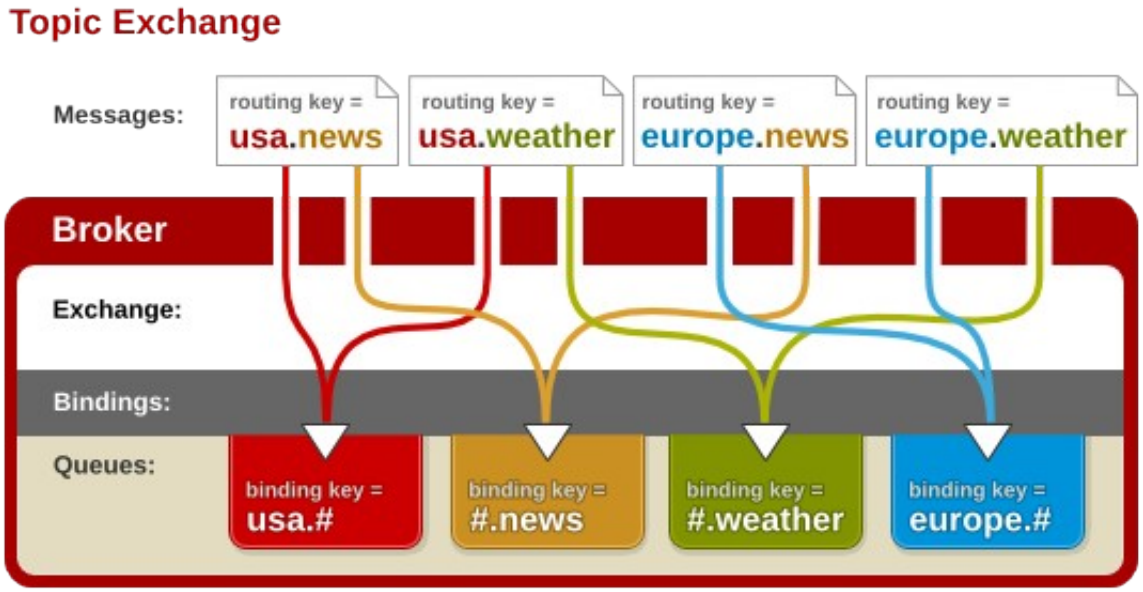


Figure 5

5.5 Bindings

The arguments supplied to exchanges to enable the routing of messages are known as bindings (see **Figure 6**). Bindings vary depending on the nature of the exchange; the direct exchange requires less binding information than the headers exchange. Notably, it is not always clear which entity should provide the binding information for a particular messaging interaction. In the direct exchange, the sender is providing the association between a routing key and the desired destination queue. This is the origin of the "destination" addressing idiom so common to JMS and other queuing products.

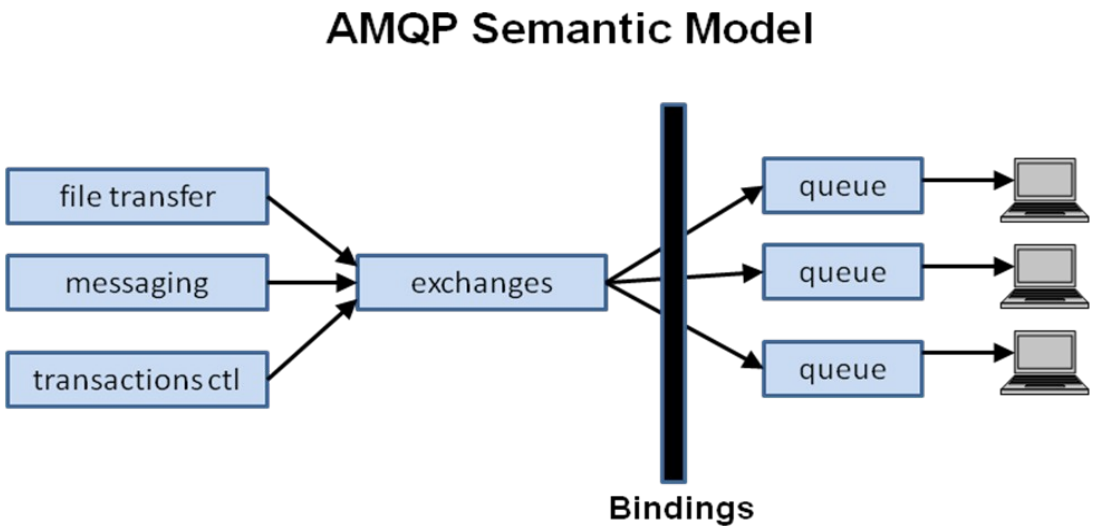


Figure 6

In the topic exchange, it is the receiving client that provides the binding information, specifying that when the topic exchange sees a message that matches any given client(s') binding(s), the message should be delivered to all of them.

AMQP has no concept of a "destination" since it does not make sense for consumer-driven messaging. It would limit its abstract routing capabilities. The concept of bindings and the convention of using a routing key as the default addressing information overcome the artificial divisions that have existed in many messaging products.

6 AMQP Communication Model

Provides a "**Shared Queue Space**" that is accessible to all interested applications:

- **Messages** are sent to an **Exchange**
- Each message has an associated **Routing Key**
- **Brokers** forward messages to one or more **Queues** based on the **Routing Key**
- Subscribers get messages from **named Queues**
- Only **one subscriber** can get a given message from each **Queue**

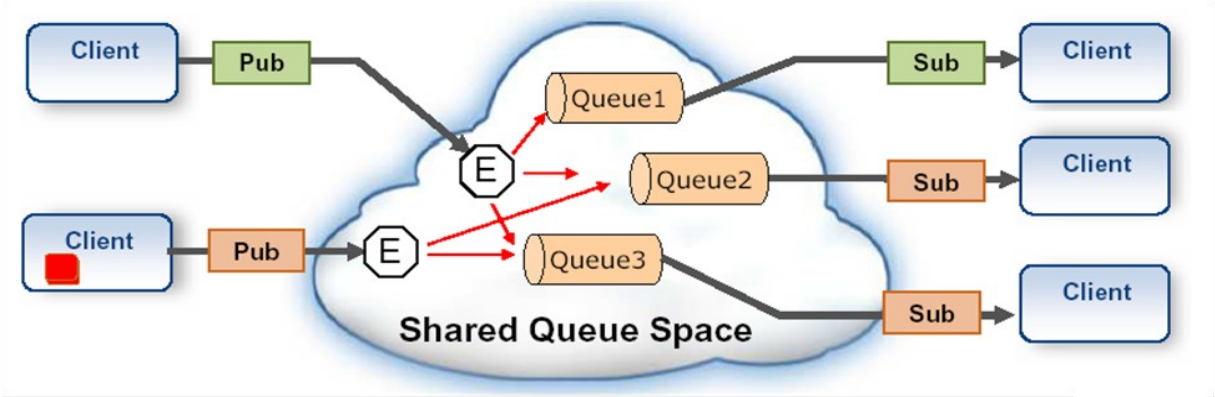


Figure 7

7 AMQP Object Model

Exchange – Receives messages and routes to a set of message queues

Queue – Stores messages until they can be processed by the application(s)

Binding – Routes messages between Exchange and Queue. Configured externally to the application – Default binding maps routing-key to Queue name

Routing Key – label used by the exchange to route Content to the queues

Content – Encapsulates application data and provides the methods to send receive, acknowledge, etc

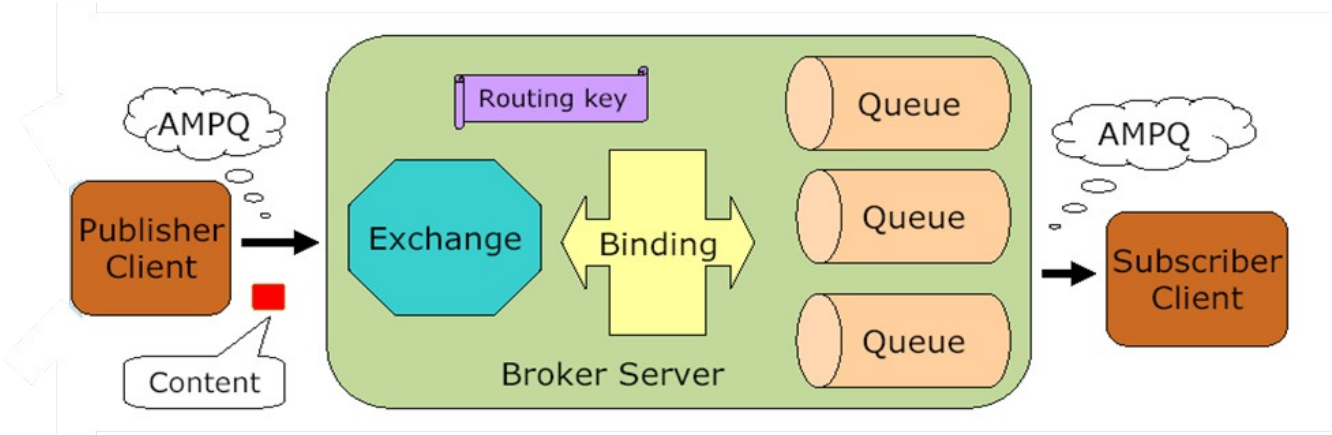


Figure 8

Performance Testing Methodology

The performance tests simulate a 3-tier configuration where producers publish to the broker and consumers subscribe to the broker.

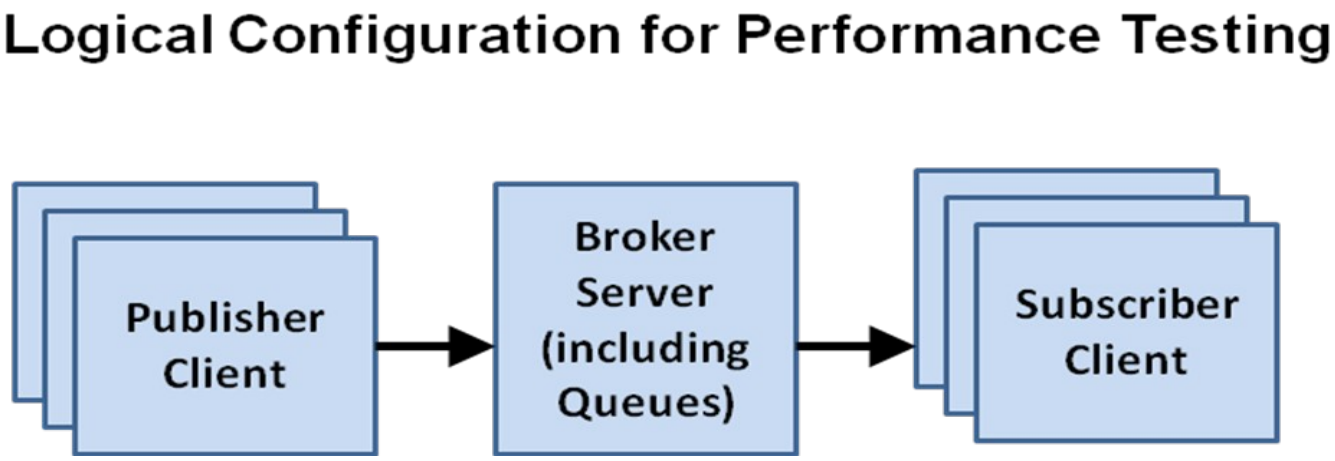


Figure 9

In the actual test setup, the Client System can run multiple instances of Publishers / Subscribers. Further, each Publisher doubles as both a Publisher and a Subscriber. Thus, a Publisher (in the Client System) generates messages which are sent to a Queue in the Broker Server and then returned to the originating Publisher (in the originating Client System) which also doubles as the Subscriber for that message.

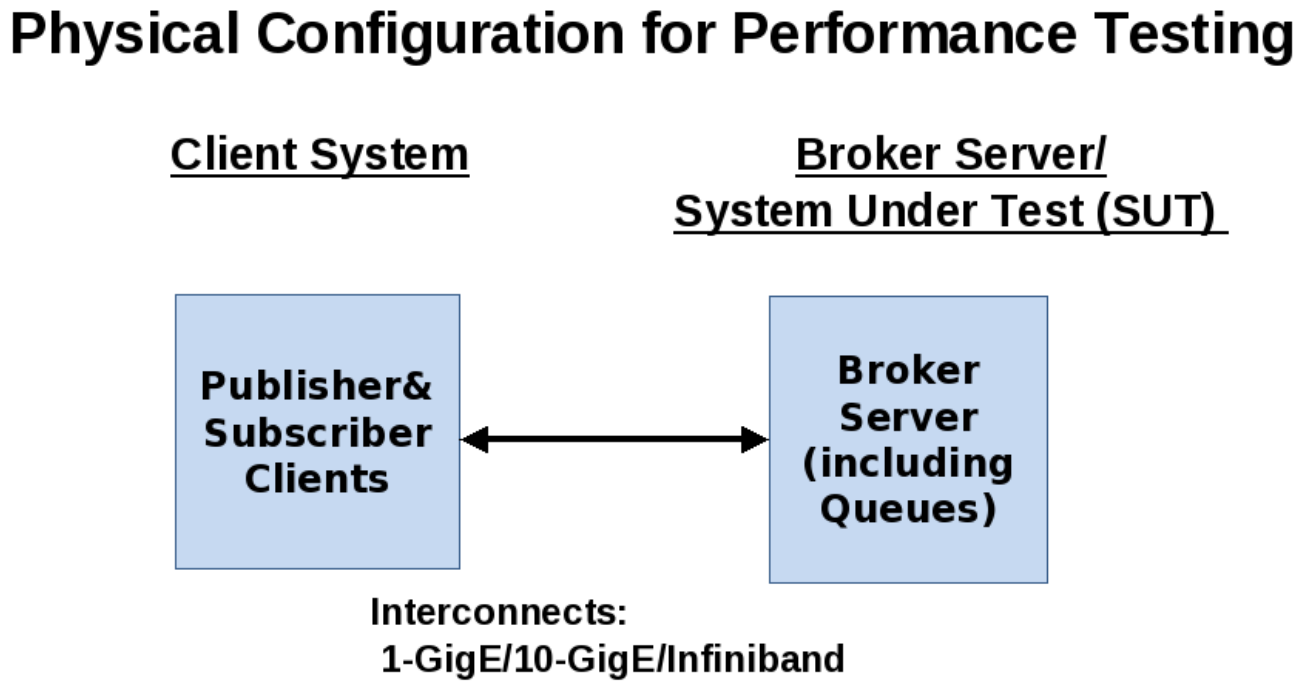


Figure 10

1 Test Harnesses

Red Hat Enterprise Linux MRG supplies AMQP test harnesses for throughput and latency testing.

1.1 Throughput (Perftest)

For throughput, `qpid-perftest` is used to drive the broker for this benchmark. This harness is able to start up multiple producers and consumers in balanced (n:n) or unbalanced(x:y) configurations.

What the test does:

- creates a control queue
- starts x:y producers and consumers
- waits for all processors to signal they are ready
- controller records a timestamp

- producers reliably en-queues messages onto the broker as fast as they can
- consumers reliably de-queue messages from the broker as fast as they can
- once the last message is received, the controller is signaled
- controller waits for all complete signals, records timestamp and calculates rate

The throughput is the calculated as the total number of messages reliably transferred divided by the time to transfer those messages.

1.2 Latency (qpid-Latency-test)

For latency, qpid-`latency-test` is used to drive the broker for this benchmark. This harness is able to produce messages at a specified rate or for a specified number of messages that are timestamped, sent to the broker, looped back to client node. All the measurements are 2-hop, from the client to the broker and back. The client will report the minimum, maximum, and average time for a reporting interval when a rate is used, or for all the messages sent when a count is used.

2 Tuning & Parameter Settings

For the testing in this paper the systems were not used for any other purposes. Therefore, the configuration and tuning that is detailed should be reviewed when other applications along with MRG Messaging.

Fine tuning the throughput tests proved difficult since the results from one data collection to another was fairly variable. This variability is a result of the fact that the test can start up a number of processes and connections. Any tuning that did not produce a significant difference compared to the variability could not be detected.

2.1 Processes

For the testing performed, the following were disabled (unless specified otherwise):

- SELinux
- cpuspeed
- irqbalance
- haldaemon
- yum-updatesd
- smartd
- setroubleshoot
- sendmail
- rpcgssd
- rpcidmapd
- rpcsvcgssd
- rhnsd
- pcscd
- mdmonitor
- mcstrans
- kdump
- isdn
- iptables
- ip6tables
- hplip
- hidd
- gpm
- cups
- bluetooth
- avahi-daemon
- restorecond
- auditd
- autofs
- certmonger
- cgred
- gfs2
- iscsi
- iscsid
- ksm
- ksmtuned
- libvirtd
- ntpd
- ntpdate
- tog-pegasus
- ebtables

2.2 SysCtl

The following kernel parameters were added to */etc/sysctl.conf*.

fs.aio-max-nr	262144	The maximum number of allowable concurrent requests.
net.ipv4.conf.default.arp_filter	1	The kernel only answers to an ARP request if it matches its own IP address.
net.ipv4.conf.all.arp_filter	1	Enforce sanity checking, also called ingress filtering or egress filtering. The point is to drop a packet if the source and destination IP addresses in the IP header do not make sense when considered in light of the physical interface on which it arrived.

Table 1

2.3 ethtool

Some of the options `ethtool` allows the operator to change relate to coalesce and offload settings. However, during experimentation only changing the ring settings had noticeable effect for throughput testing.

```
1Gb Network
# ethtool -g eth0
Ring parameters for eth0:
Pre-set maximums:
RX:         4096
RX Mini:    0
RX Jumbo:   0
TX:         4096
Current hardware settings:
RX:         256
RX Mini:    0
RX Jumbo:   0
TX:         256

# ethtool -G eth0 rx 4096 tx 4096
# ethtool -g eth0
Ring parameters for eth0:
Pre-set maximums:
RX:         4096
RX Mini:    0
RX Jumbo:   0
TX:         4096
Current hardware settings:
RX:         4096
RX Mini:    0
RX Jumbo:   0
TX:         4096


10GigE Network

# ethtool -g eth2
Ring parameters for eth2:
Pre-set maximums:
RX:         8192
RX Mini:    0
RX Jumbo:   0
TX:         8192
Current hardware settings:
RX:         1024
RX Mini:    0
RX Jumbo:   0
TX:         512


# ethtool -G eth2 rx 8192 tx 8192
```

```
# ethtool -g eth2
Ring parameters for eth2:
Pre-set maximums:
RX:         8192
RX Mini:    0
RX Jumbo:   0
TX:         8192
Current hardware settings:
RX:         8192
RX Mini:    0
RX Jumbo:   0
TX:         8192
```

2.4 dirty-ratio

`Dirty-ratio` was increased to match the default settings of RHEL5. The default settings were determined to be too low for these workloads.

```
# cat /proc/sys/vm/dirty_ratio
20
# echo 40 > /proc/sys/vm/dirty_ratio
# cat /proc/sys/vm/dirty_ratio
40
#
```

2.5 CPU affinity

For latency testing, all interrupts from the cores of one CPU socket were reassigned to other cores. The interrupts for the interconnect under test were assigned to cores of this vacated socket. The processes related to the interconnect (e.g. `ib_mad`, `ipoib`) were then scheduled to run on the vacated cores. The Qpid daemon was also scheduled to run on these or a subset of the vacated cores. How `qpid-latency-test` was scheduled was determined by the results of experiments limiting or not limiting the `qpid-latency-test` test process to specific cores. Experiments with `qpid-perftest` show that typically the best performance was achieved with the affinity settings after a boot without having been modified.
Interrupts can be re-assigned to specific cores or set of cores. */proc/interrupts* can be queried to identify the interrupts for devices and the number of times each CPU/core has handled each interrupt. For each interrupt, a file named */proc/irq/<IRQ #>/smp_affinity* contains a hexadecimal mask that controls which cores can respond to specific interrupt. The contents of these files can be queried or set.

Processes can be restricted to run on a specific set of CPUs/cores. `taskset` can be used to define the list of CPUs/cores on which processes can be scheduled to execute. Also,numactl can be used to define the list of Sockets on which processes can be scheduled to execute

The MRG – Realtime product includes the application, `tuna`, which allows for easy setting of affinity of interrupts and processes, via a GUI or command line.

2.6 AMQP parameters

Qpid parameters can be specified on the command line, through environment variables or through the Qpid configuration file.

The tests were executed with the following `qpidd` options:

--auth no	disable connection authentication, makes setting the test environment easier
--mgmt-enable no	disable management data collection
--tcp-nodelay	disable packet batching
--worker-threads <#>	set the number of IO worker threads to <#> This was used only for the latency tests, where the range used was between 1 and the numbers of cores in a socket plus one. The default, which was used for throughput, is one more than the total number of active cores.

Table 2

Table 3 details the options specified for *qpid-perftest*. For all testing in this paper a *count* of 100000 was used. Experimentation was used to detect if setting *tcp-nodelay* was beneficial. For each *size* reported, the *npubs* and *nsubs* were set equally from 1 to 8 by powers of 2 while *qt* was set from 1 to 8, also by powers of 2. The highest value for each *size* is reported.

--nsubs <#> --npubs <#>	number of publishers/ subscribers per client
--count <#>	number of messages send per pub per qt, so total messages = count * qt * (npub+nsub)
--qt <#>	number of queues being used
--size <#>	message size
--tcp-nodelay	disable the batching of packets
--protocol <tcp| rdma>	used to specify RDMA, default is TCP

Table 3

The parameters used for *qpid-latency-test* are listed in **Table 4**. A 10000 message *rate* was chosen since all the test interconnects would be able to maintain this rate. When specified, the *max-frame-size* was set to 120 more than the size. When a *max-frame-size* was specified, *bound-multiplier* was set to 1.

--rate <#>	target message rate
--size <#>	message size
--max-frame-size <#>	the maximum frame size to request, only specified for ethernet interconnects
--bounds-multiplier <#>	bound size of write queue (as a multiple of the max frame size), only specified for ethernet interconnects
--tcp-nodelay	disable packet batching
--protocol <tcp| rdma>	used to specify RDMA, default is TCP

Table 4

Hardware/Software Versions

1 Hardware

Client System	HP DL380 G56 Dual Socket, Quad Core (Total of 8 cores) Intel Xeon X5570 @ 2.93GHz 24 GB RAM
Broker Server	Intel Westmere Dual Socket,Six Core (Total of 12 cores) Intel Xeon X5670 @ 2.93 GHz 24 GB RAM

Table 5

2 Network

All load driver (client) systems have point-to-point connections to the system under test (SUT). Network cards used during the sessions were:

1 GigE Adapter	DL380 - Embedded Broadcom Corporation NetXtreme II BCM5709 Gigabit Ethernet Westmere - Embedded Intel Corporation 82576 Gigabit Network
10 GigE Adapters	Mellanox Technologies MT26448 [ConnectX EN 10GigE, PCIe 2.0 5GT/s] direct connect with SR Fibre
Infinband HCA	InfiniHost III Lx HCA – HCA.Cheetah-DDR.20 direct connect

Table 6

3 Software

Qpid	0.7.946106-7.el6
Red Hat Enterprise Linux	2.6.32-71.el6.test.x86_64
bnx2	2.0.8-j15
Igb	2.1.0-k2
mlx4_en	1.4.1.1
mthca	1.1.0
ofed/openib	1.4.1.1

Table 7

Performance Results

1 Latency

`qpid-Latency-test,` with specified options, reports the minimum, maximum, and average latency for each 10,000 messages sent every second. The test runs performed collected 100 seconds of data for each size.

Each graph of latency results, plots 100 averages for each size tested. The legend on the right side identifies the transfer size with the average of the 100 values in parenthesis.

1.1 1-GigE

As expected, the latency increases with on-board 1GigE with the transfer size.

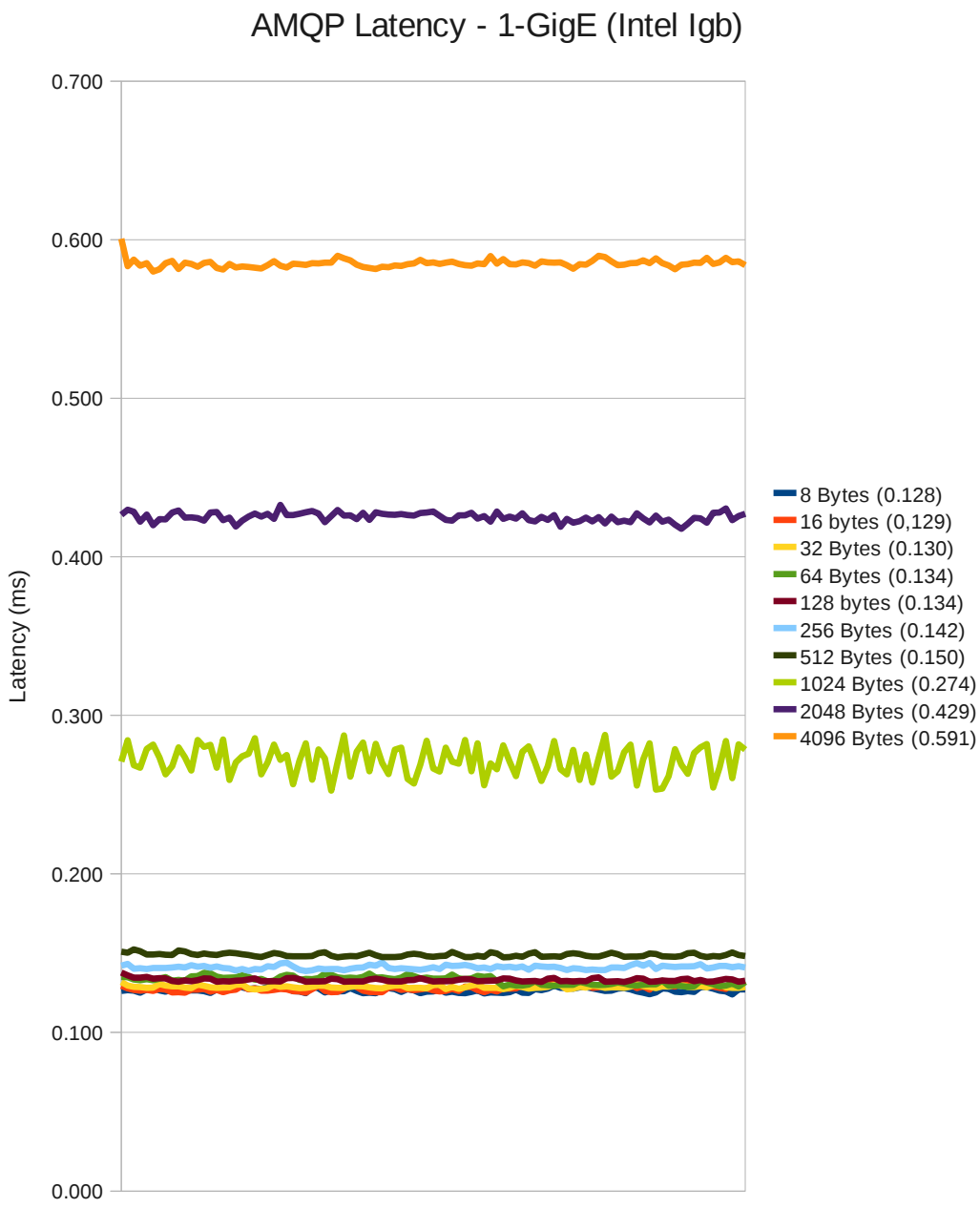


Figure 11

1.2 10-GigE

The latencies for Mellanox 10-GigE are lower than those of 1-GigE and IPoIB. This is the only interface where the latencies do not consistently increase as the transfer size gets larger using TCP/IP protocol.

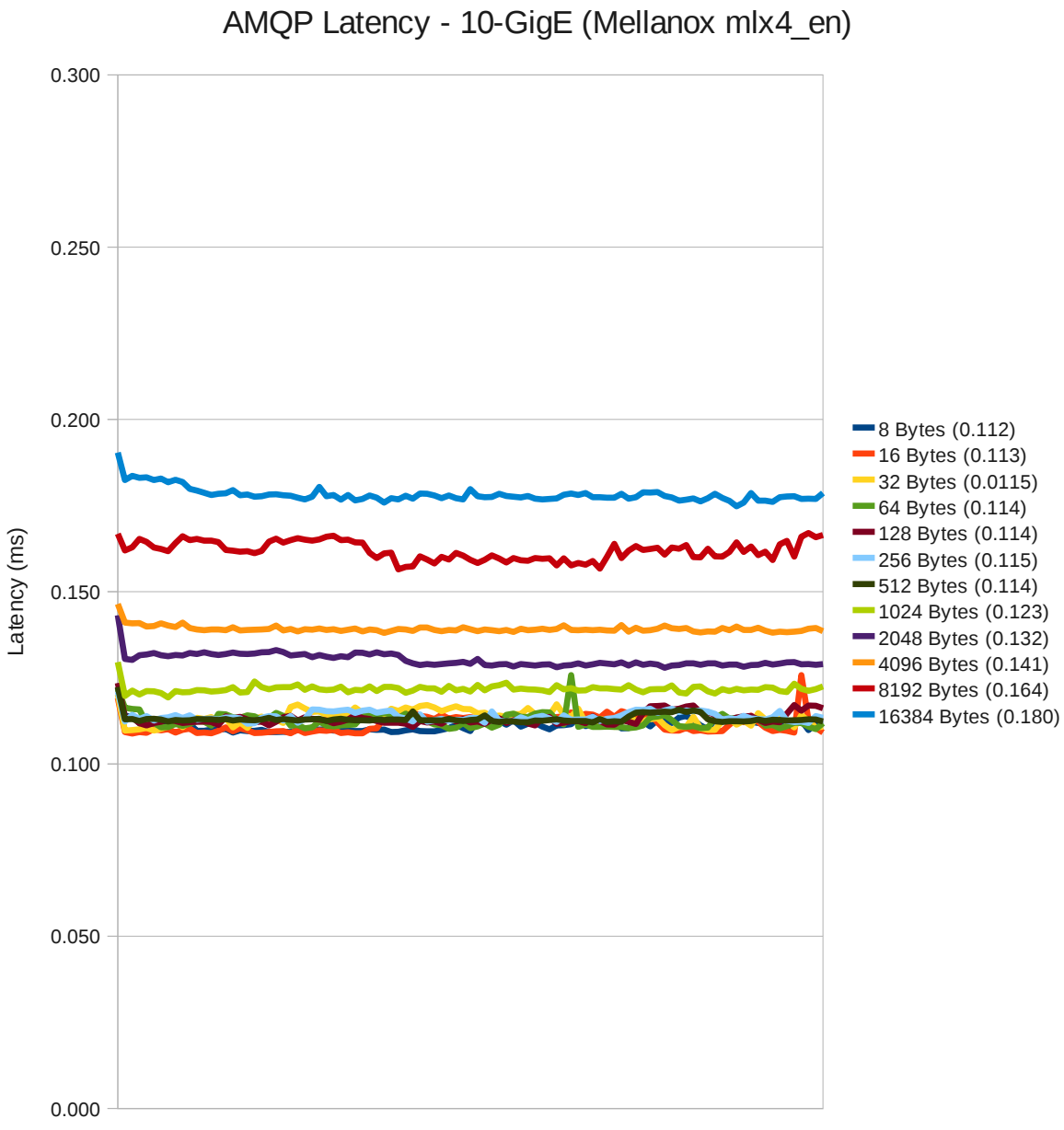


Figure 12

1.1.3 Internet Protocol over InfiniBand (IPoIB)

The IPoIB data is grouped more closely except for the larger transfer sizes.

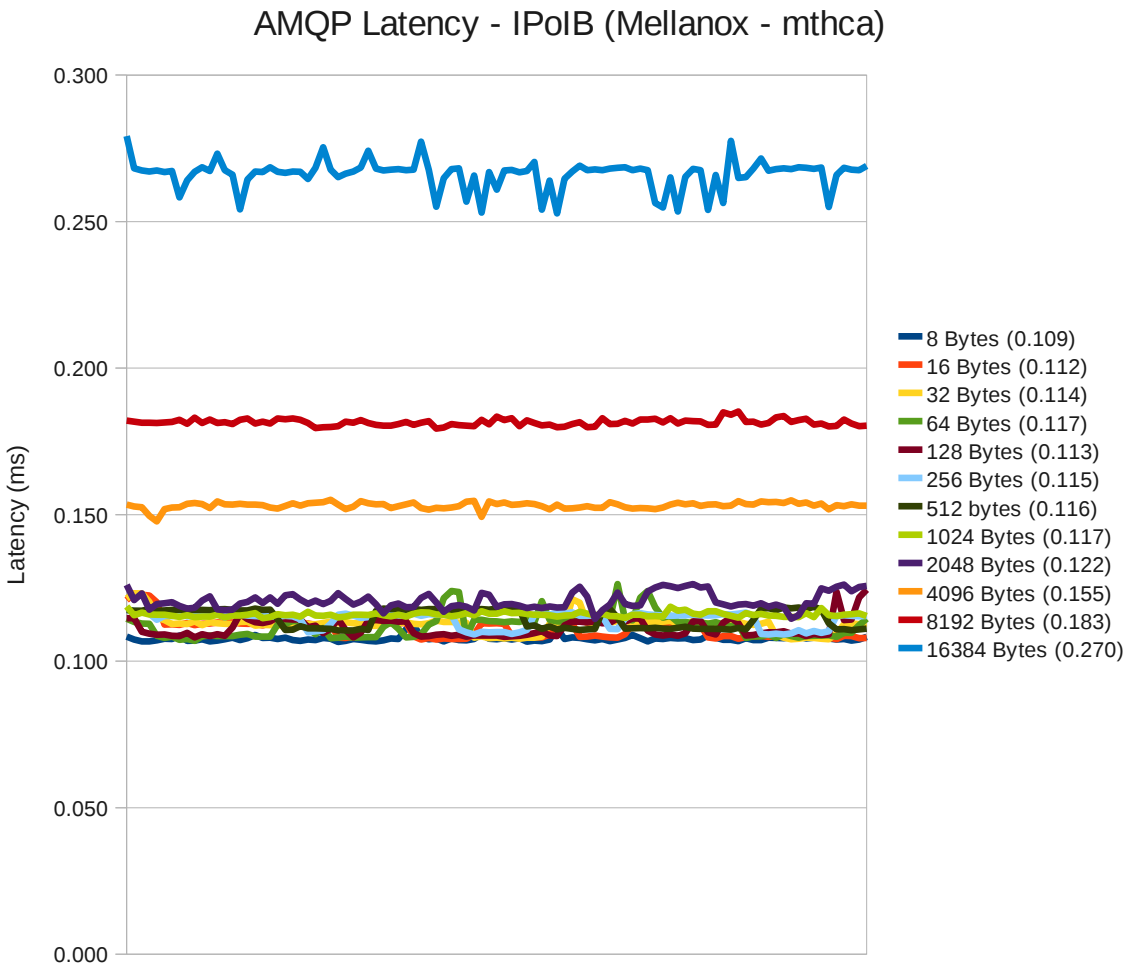


Figure 13

1.14 Remote Direct Memory Access (RDMA) with Mellanox 10Gig E

The Mellanox 10GigE with RDMA over Converged Ethernet (RoCE), results are the lowest and most closely grouped of all the latency measurements.

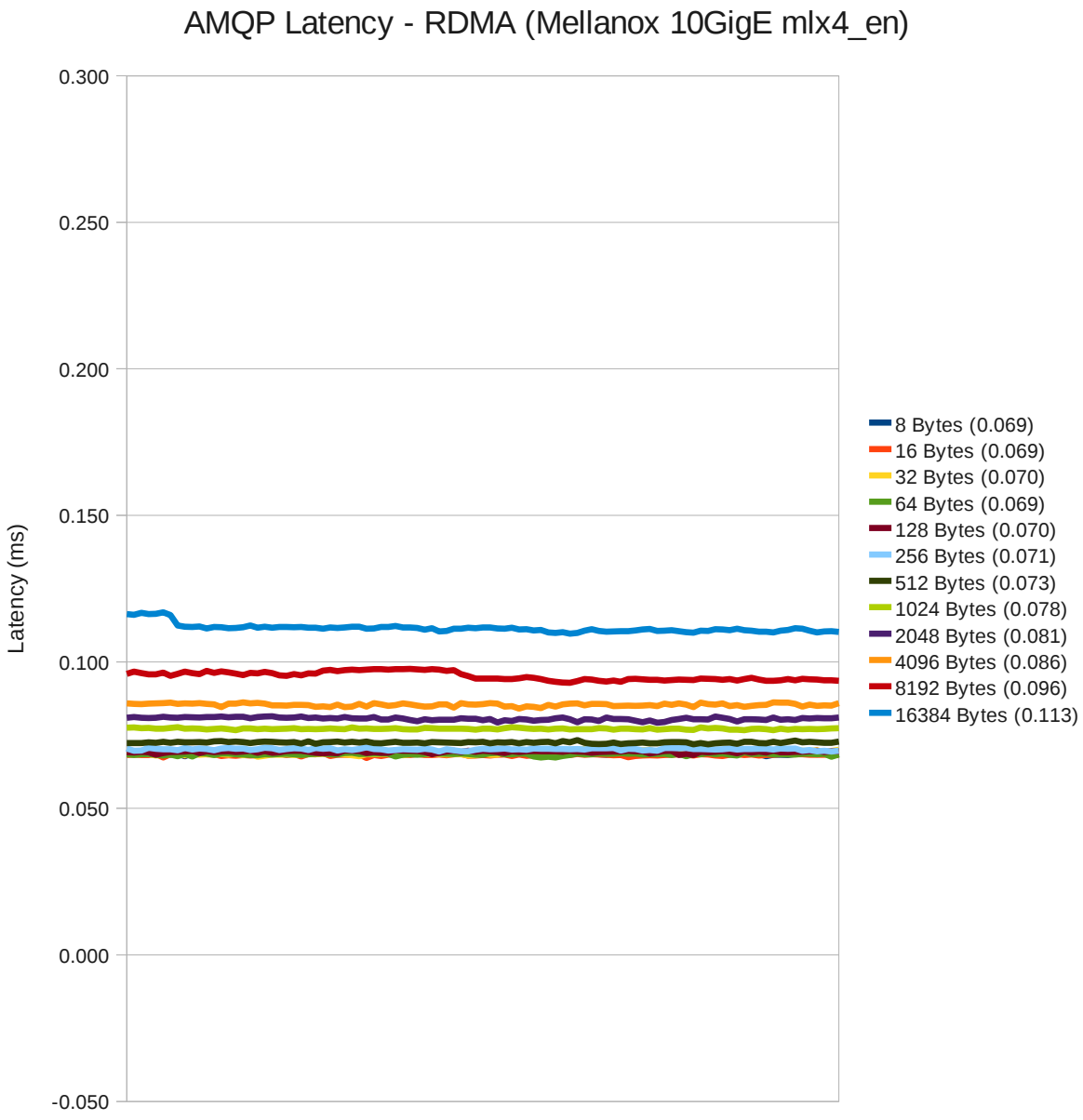
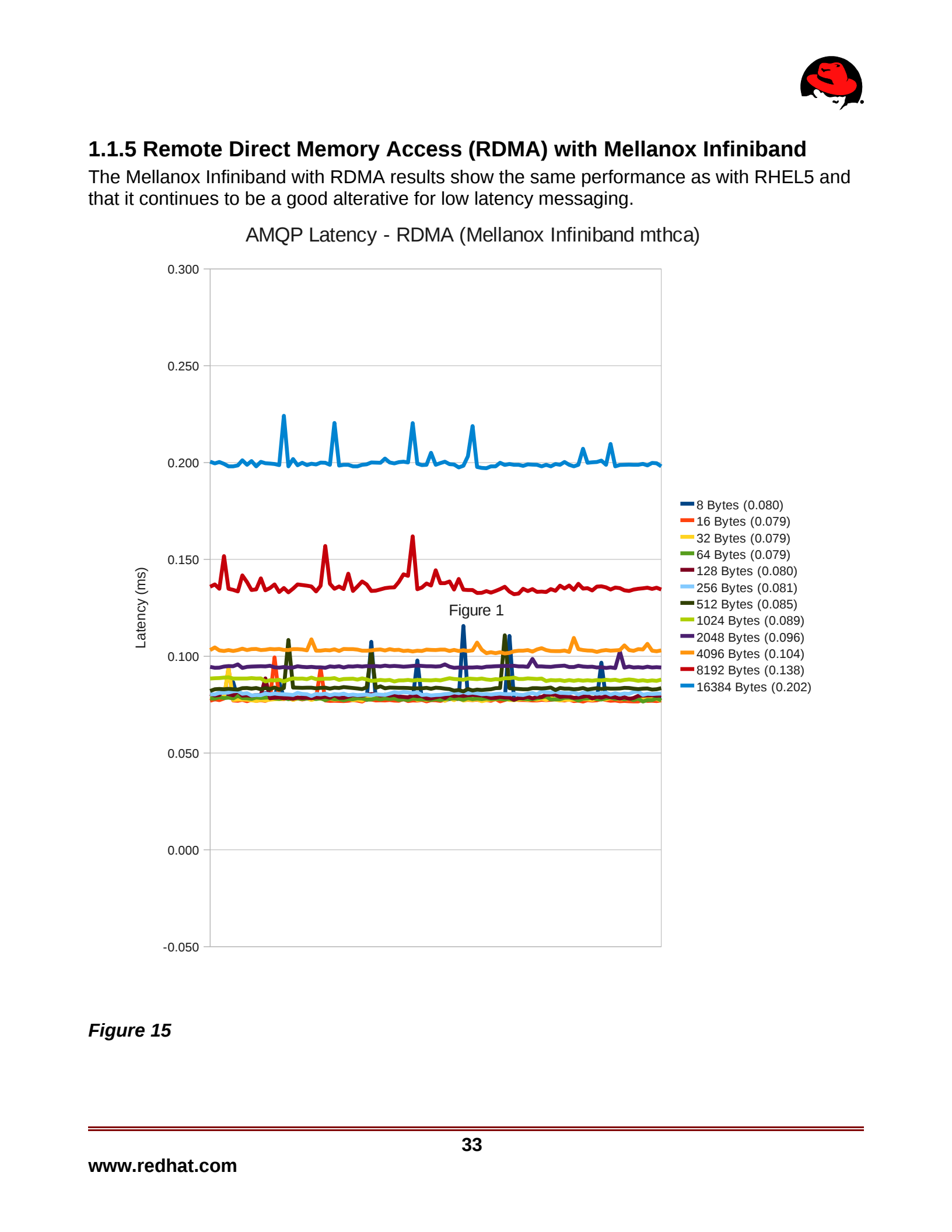


Figure 14



1.1.5 Remote Direct Memory Access (RDMA) with Mellanox Infiniband

The Mellanox Infiniband with RDMA results show the same performance as with RHEL5 and that it continues to be a good alterative for low latency messaging.

Figure 15

1.3 5.16 Comparisons

The averages for three commonly used message sizes are plotted for each of the interconnects/protocols. For each of the plots, 1-GigE has the highest latency. Considerably less, but consistently second, is IPoIB. The 10 GigE results follow next. The 10GigE and IB RDMA results are considerably quick, providing the lowest latency.

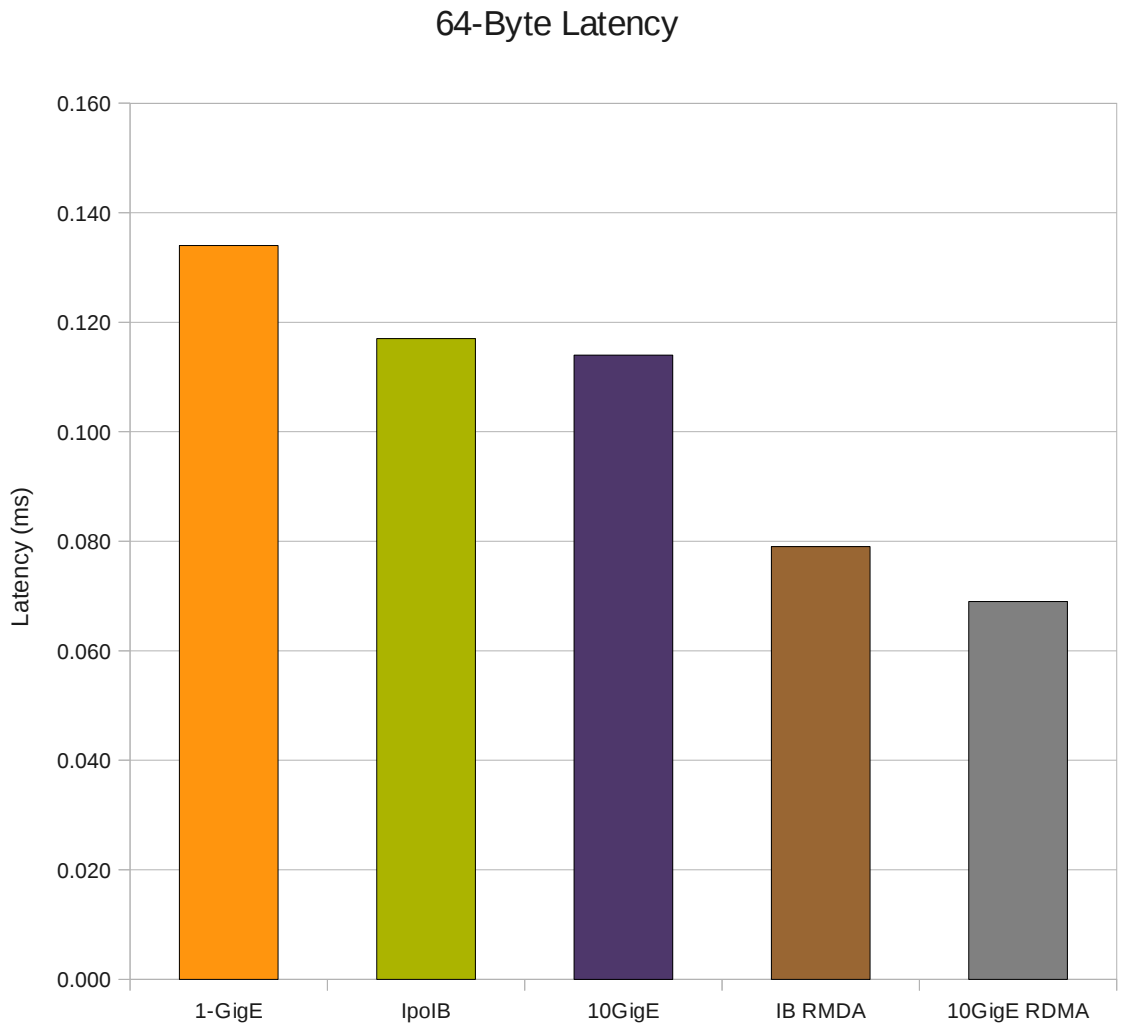


Figure 16

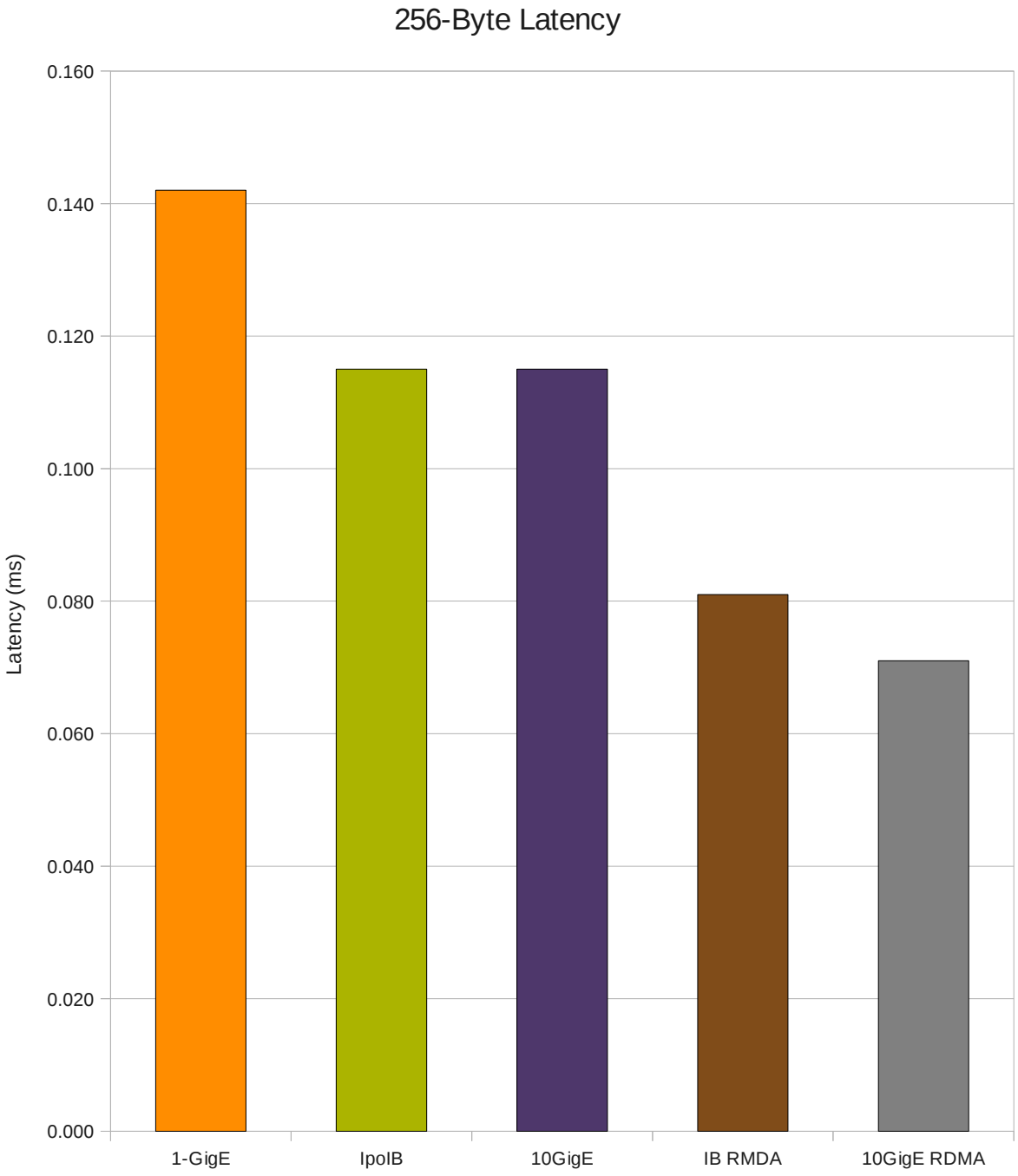

256-Byte Latency
Latency (ms)
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
1-GigE
IpoIB
10GigE
IB RMDA
10GigE RDMA

Figure 17

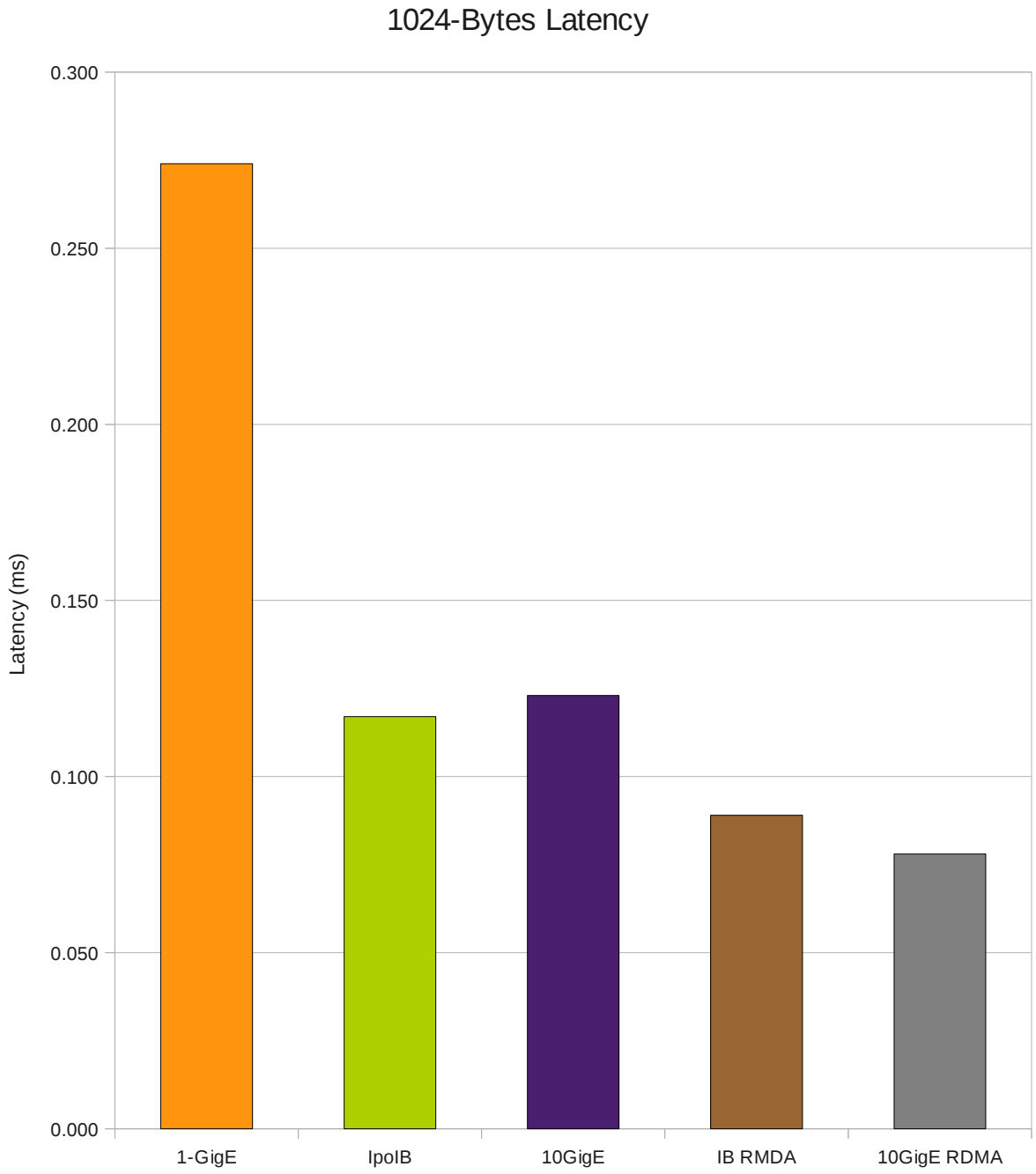

1024-Bytes Latency
Latency (ms)
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1-GigE
IpoIB
10GigE
IB RMDA
10GigE RDMA

Figure 18

2 Throughput

The following bar graphs present the best throughput results for each transfer size for each of the interconnects/protocols. The blue bars represent the number of transfers per second and use the left sided y-axis scale of 1000 transfers per second. The red bars illustrate the corresponding MB/s and use the rigth sided y-axis scale. The scales are consistent for all the interconnects/protocols.

In general, smaller transfer sizes were limited by the number of transfers the network stack could perform, however the larger results are limited by the line capacity of the interconnect.

Higher thoughput may be achieved using multiple interfaces simultaneously.

2.1 1-GigE

The maximum transfers per second, 547466, occur using the 32-byte transfer size. The maximum throughput tops out at 213 MB/s.

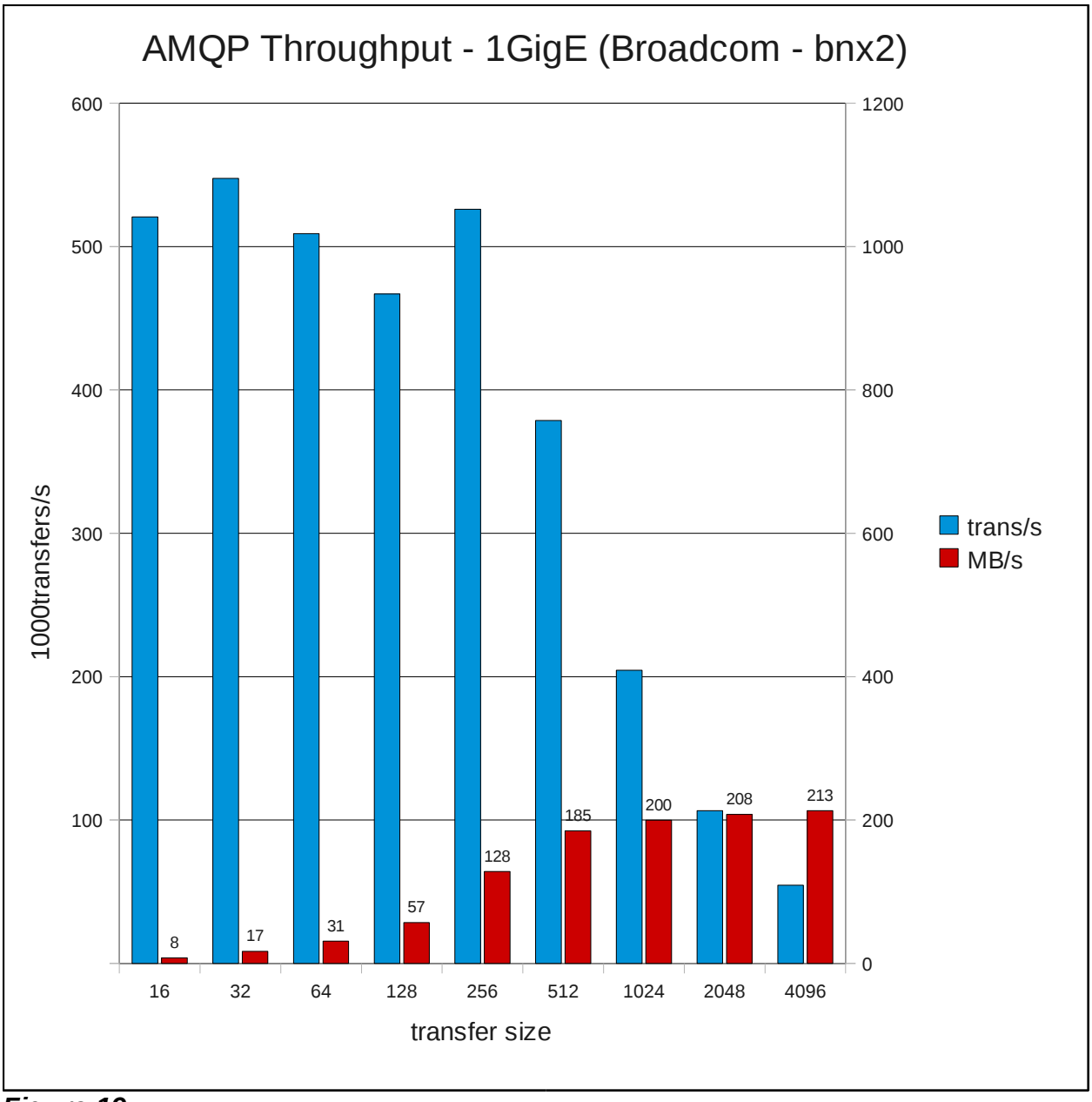


Figure 19

2.2 10-GigE

The higher line capacity of 10-GigE yeilds 1,225,493 8-byte transfers per second and tops out at 2003 MB/s.

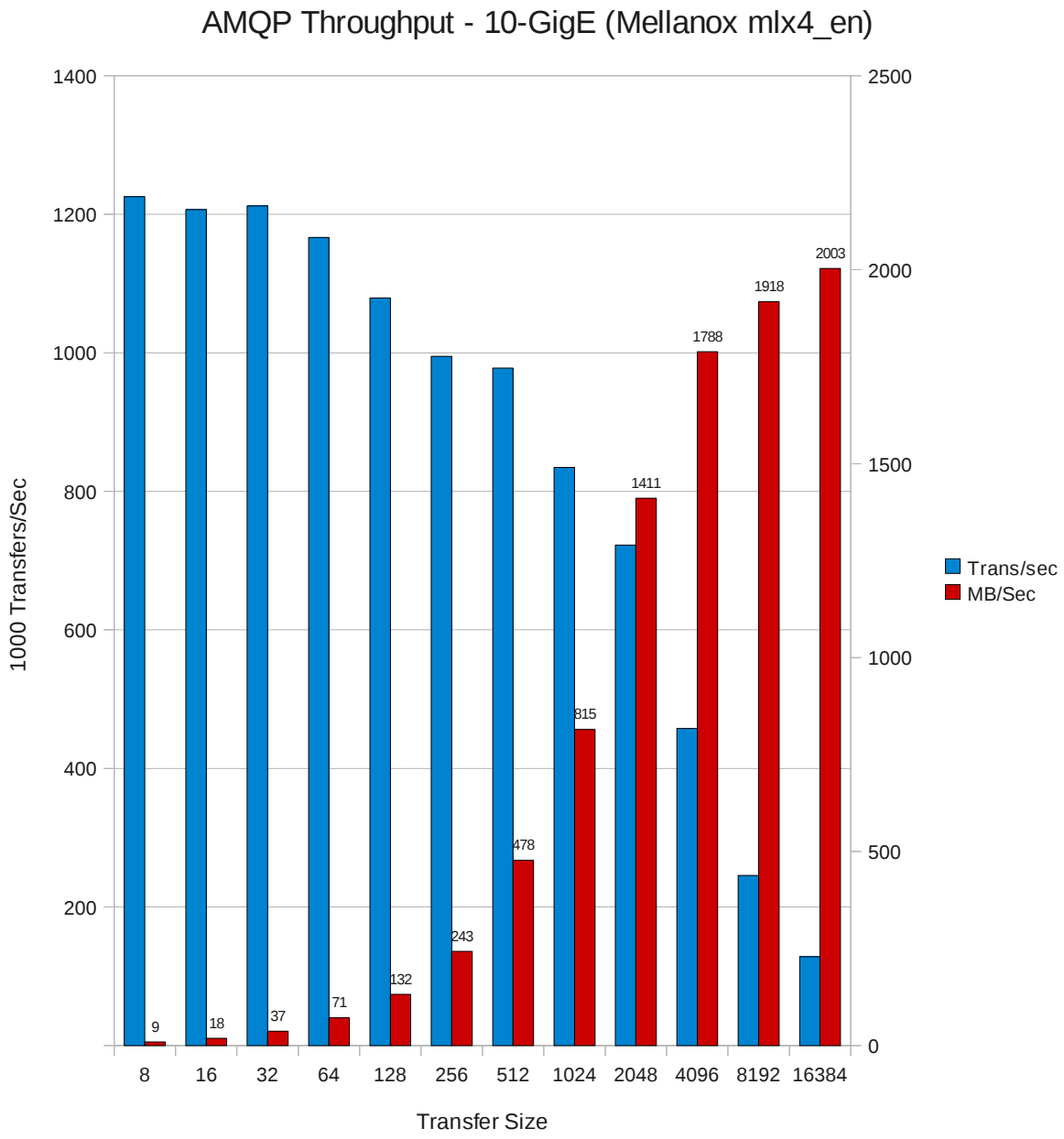


Figure 20

2.3 IPoIB

The 16-byte tranfsers again prove to yield the highest transfer rate, 1,132,544. The throughput peaks at 351 MB/s.

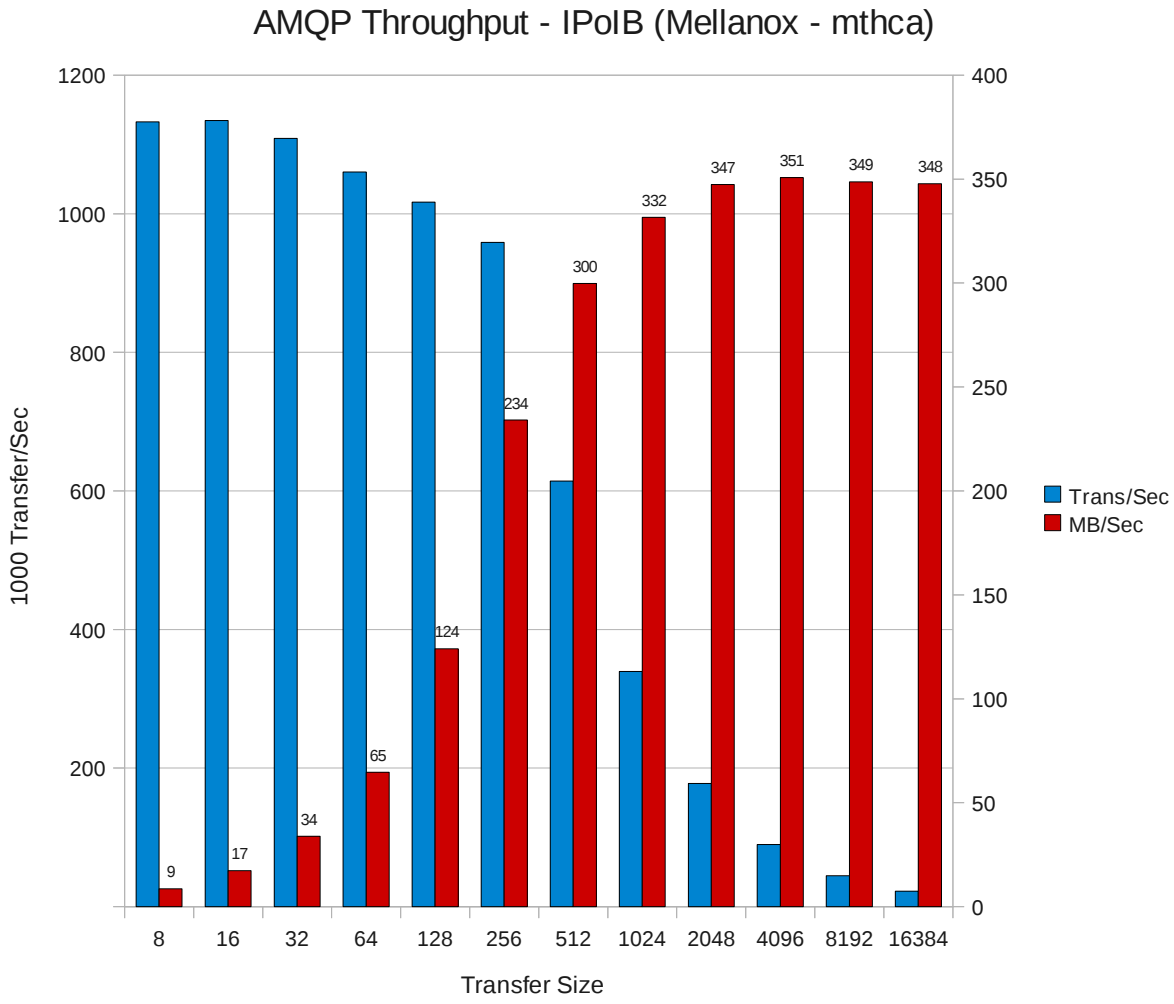


Figure 21

2.4 10-Gig-E RDMA

Using 10-GigE with RDMA improves the large transfer throughput rate producing the overall highest rate of 2068 MB/s. The most transfers,1,11218, were for 16-bytes.

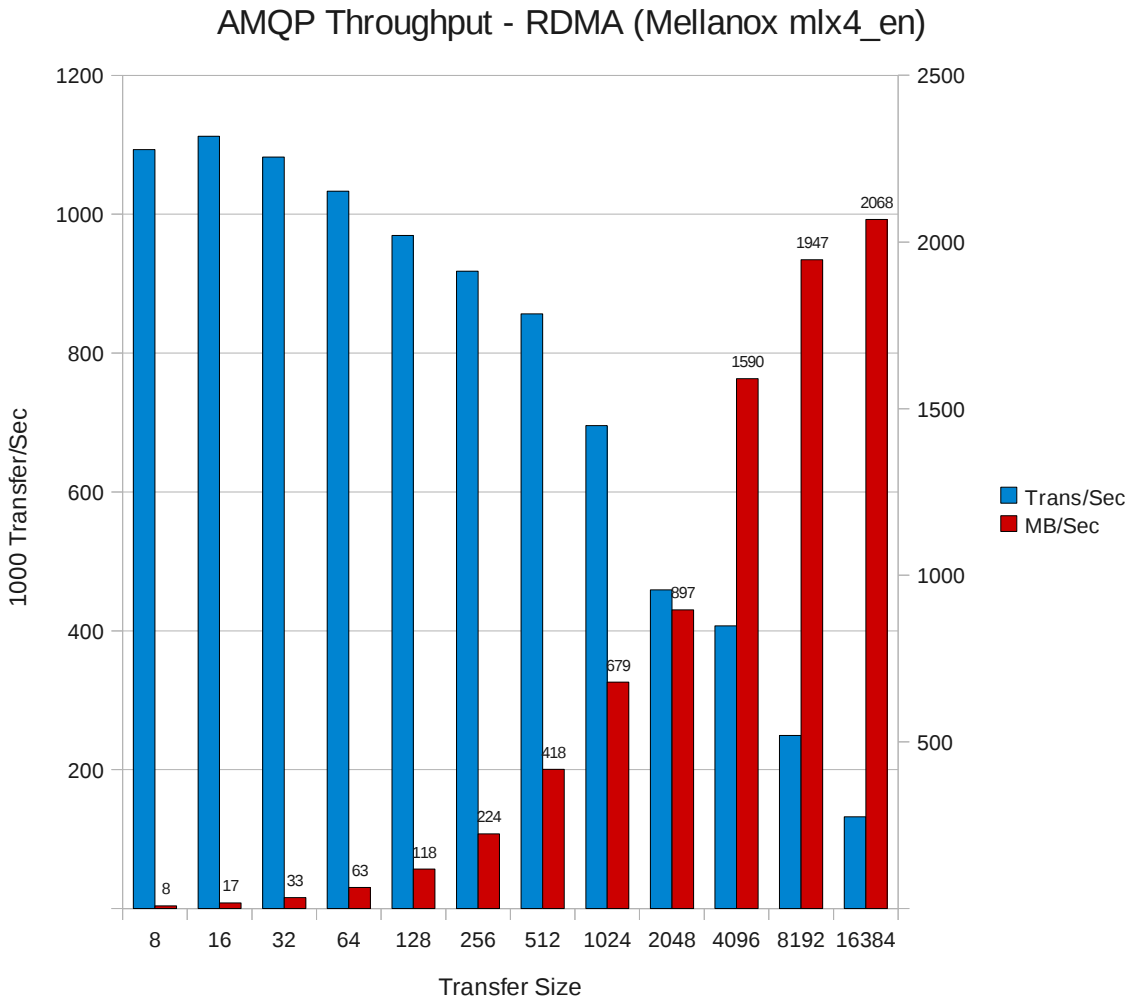


Figure 22

2.5 IB RDMA

For RDMA the 8-byte transfers/s slight beat out the 16-byte results at 1,092,358. The throughput tops out at 489 MB/s.

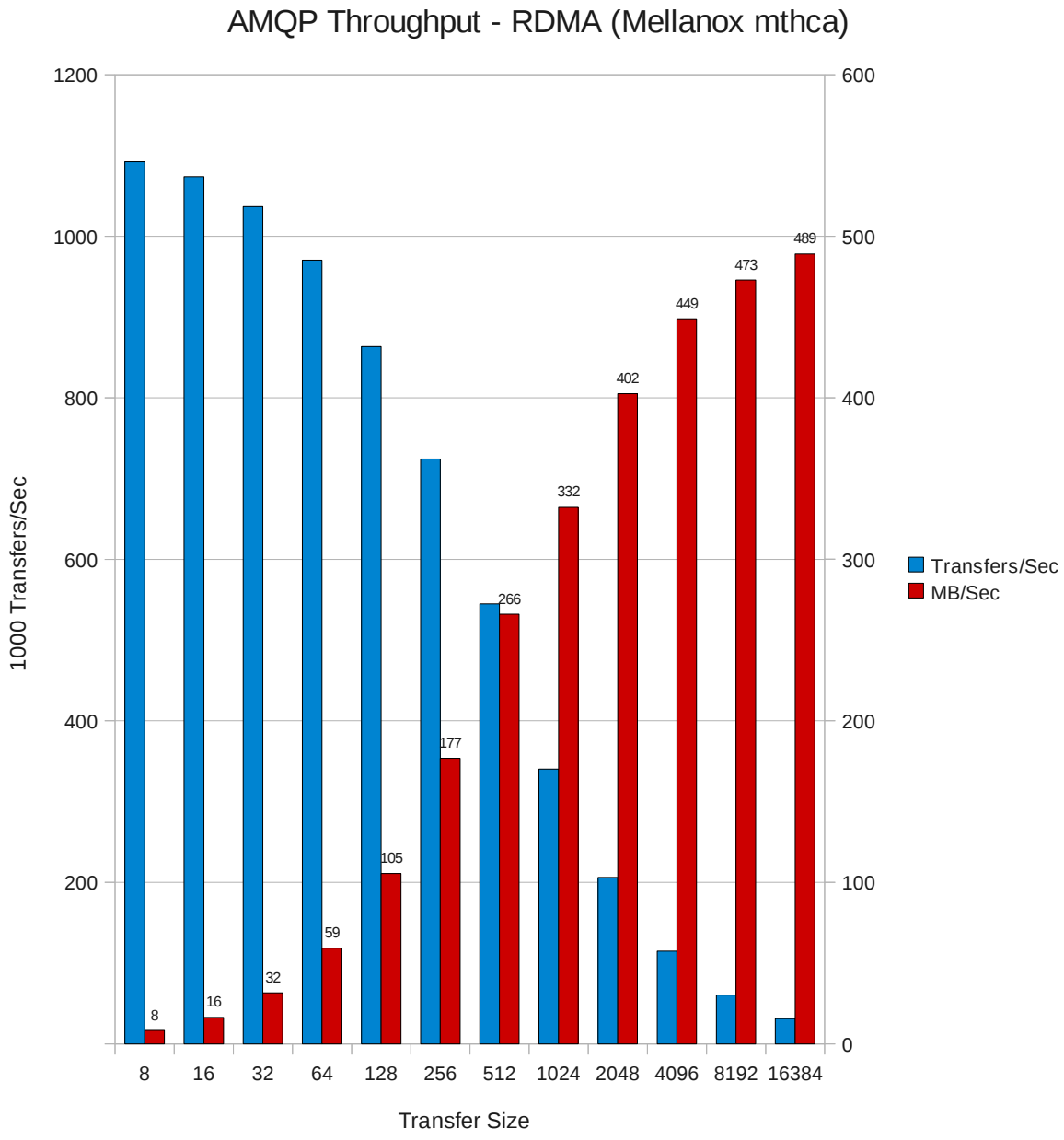


Figure 23

2.6 Comparisons

Charting the throughput of the same common transfer sizes for the various interconnects/protocols show the results are consistent with the latency results.For the 64-byte transfer, 10-GigE performs best, followed by 1-GigE, IPoIB, 10-GigE RDMA, then IB RDMA.

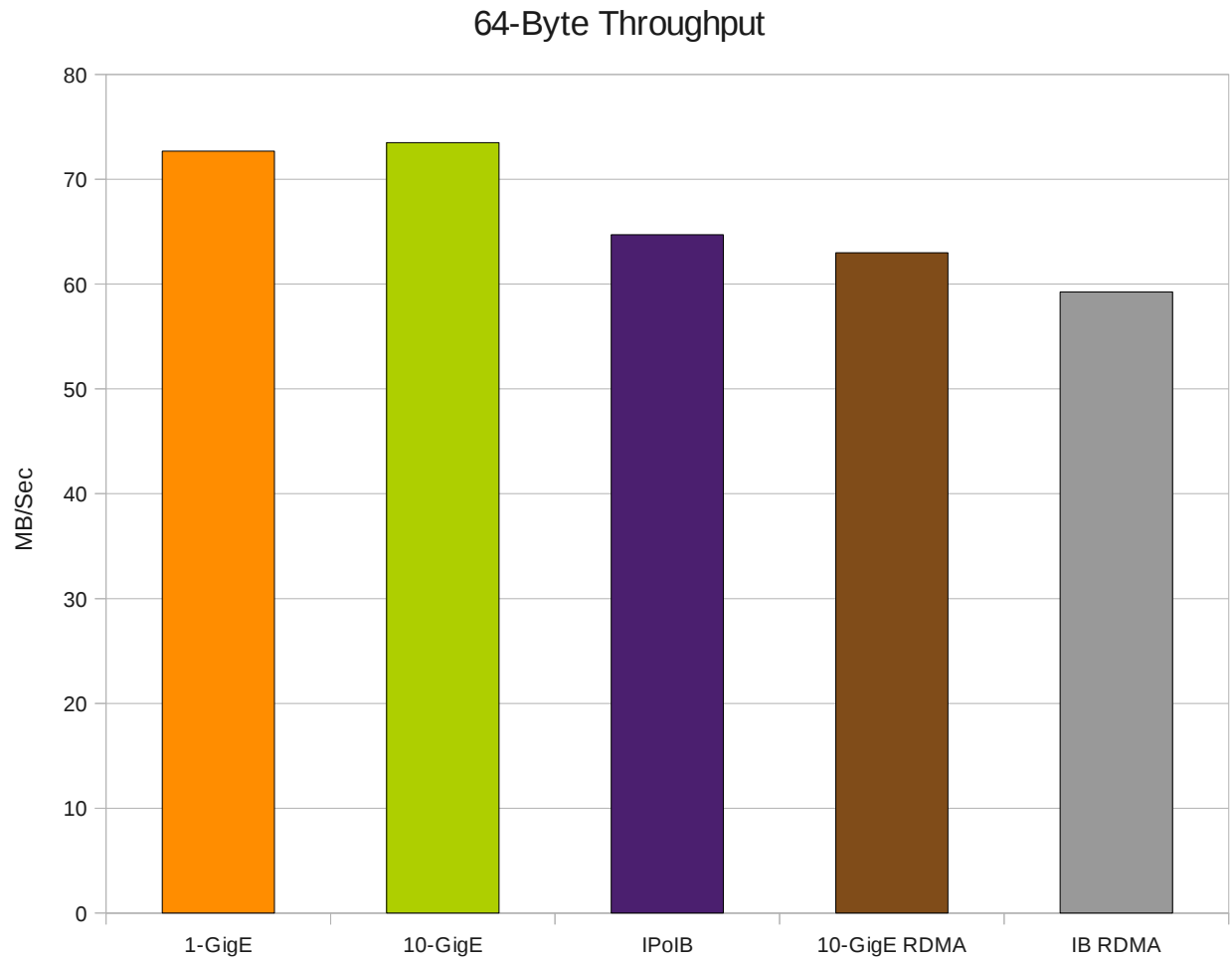


Figure 24

The order changes for 256-byte transfers. 10-GigE wins with 1-GigE less than a 1 MB/s behind. IPoIB, 10-GigE RDMA, IB RDMA finish out the order.

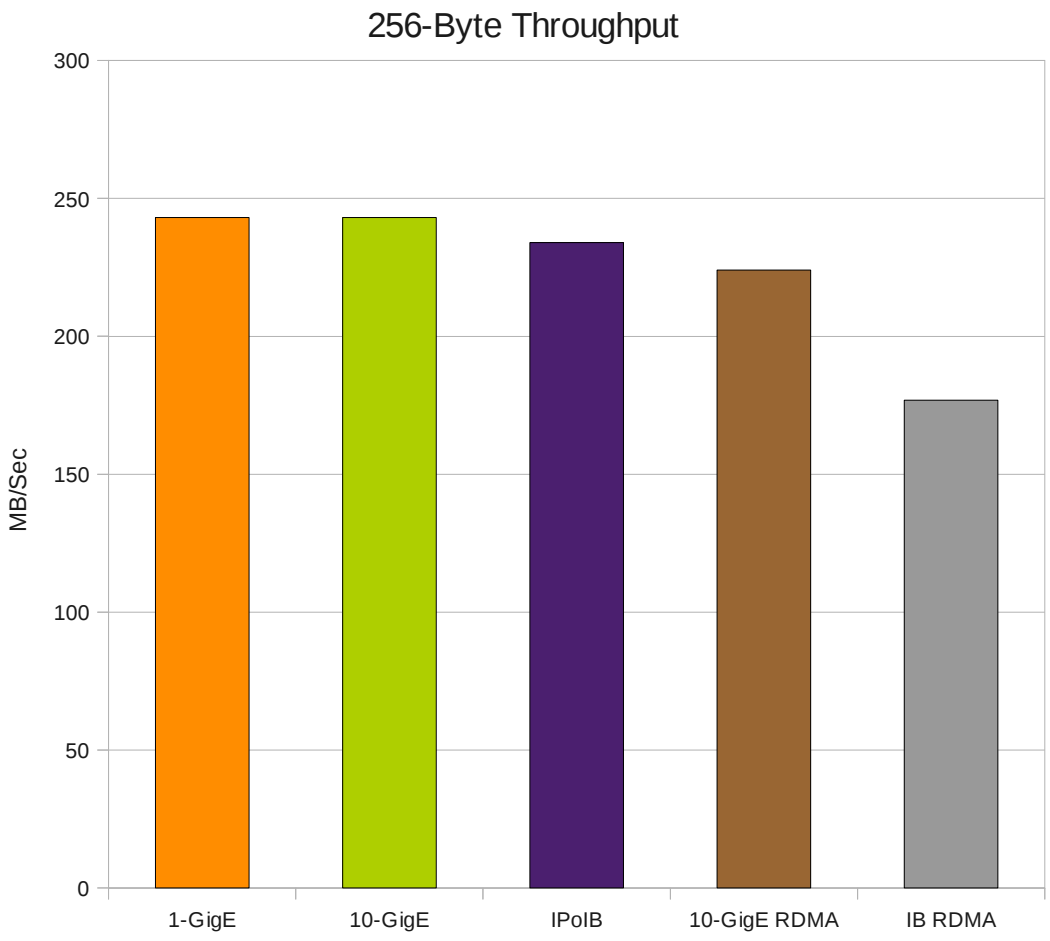

256-Byte Throughput
MB/Sec
300
250
200
150
100
50
0
1-GigE
10-GigE
IPoIB
10-GigE RDMA
IB RDMA

Figure 25

Using a 1K-byte transfer, 10-GigE wins, followed by 10-GigE RDMA, IB RDMA, IPoIB, then 1-GigE.

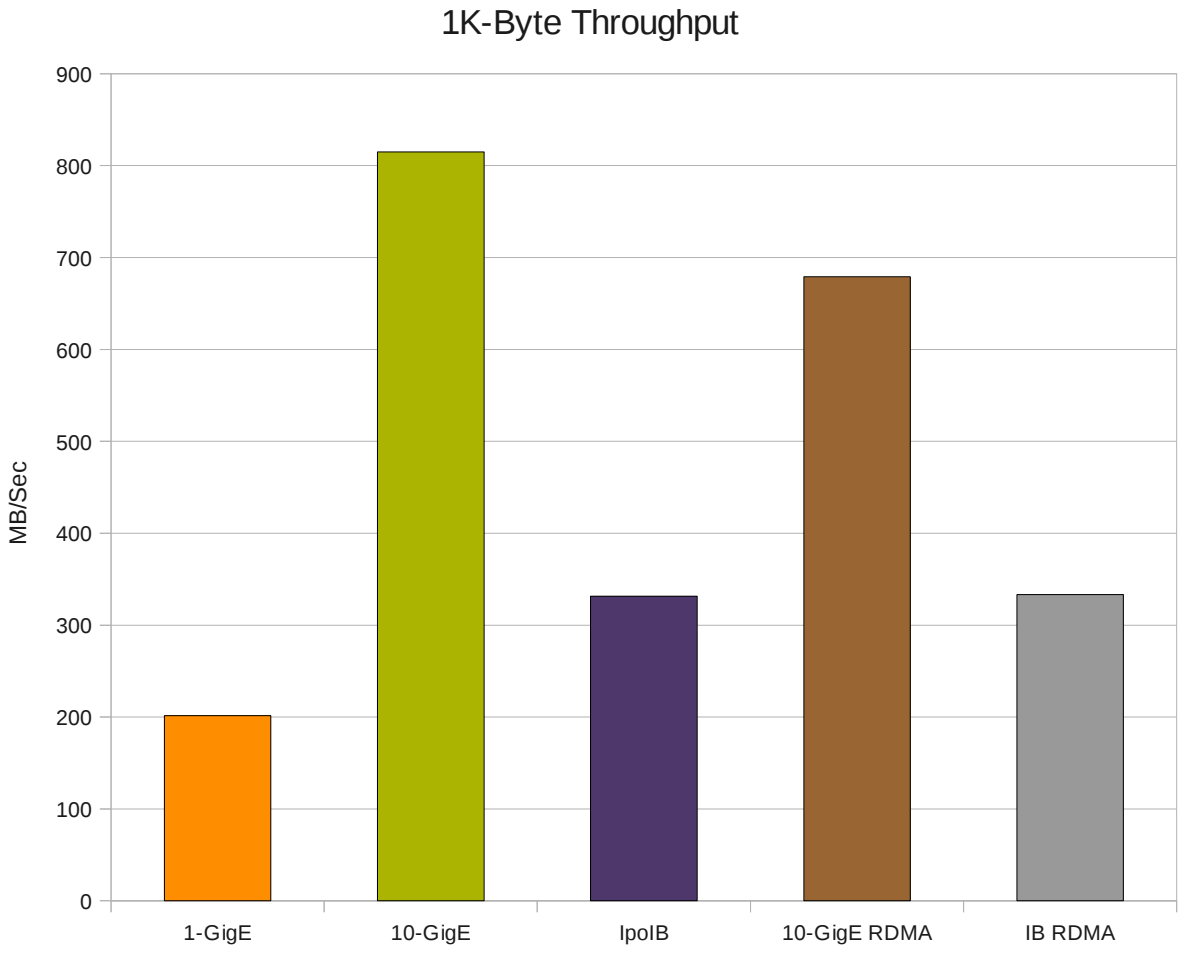


Figure 26

3 System Metrics

This section presents various system metrics that were collected during 64-byte throughput tests for the various interconnects/protocols.

The first is Memory Usage. IB RDMA uses a significant amount of memory compared to the other options. 10 GigE and IPoIB uses the least.

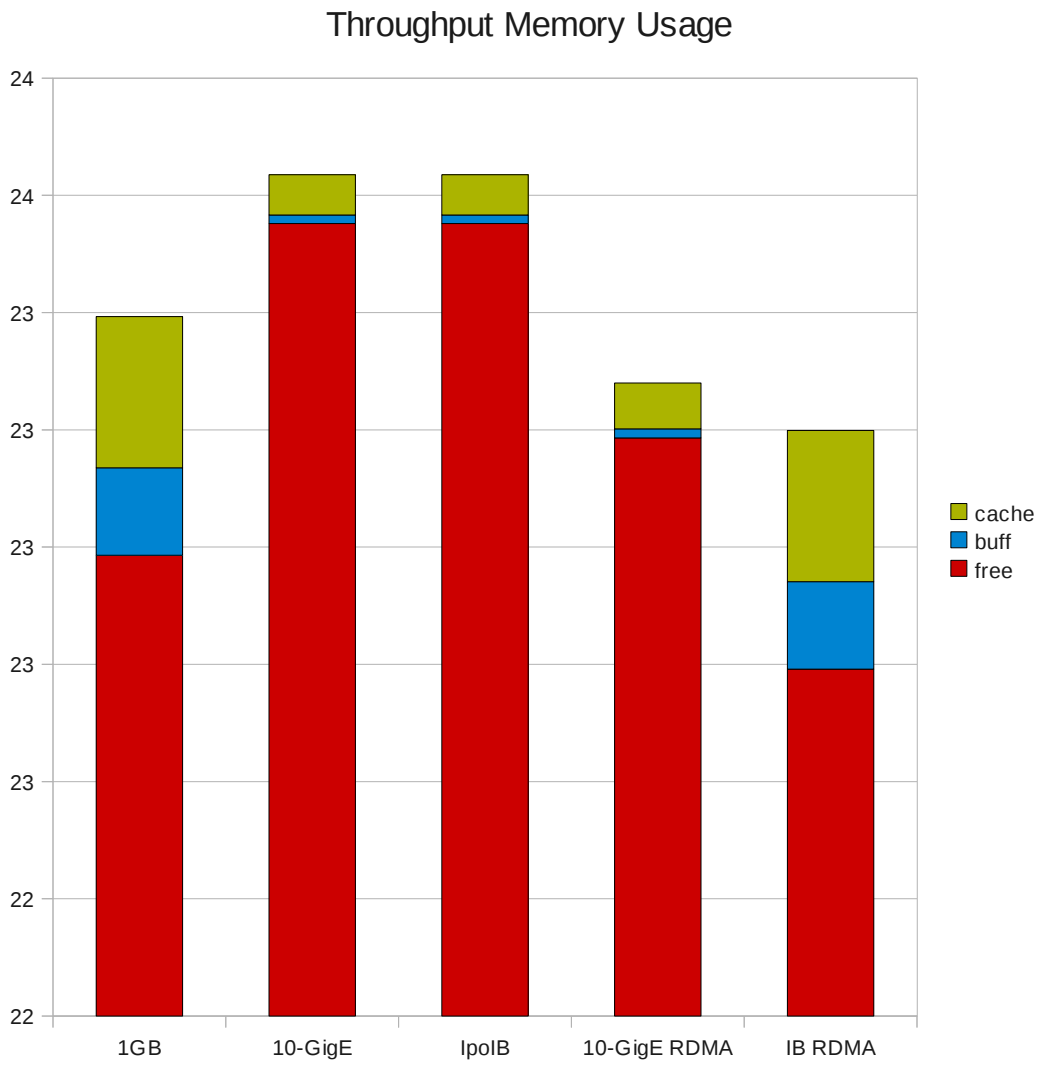


Figure 27

IB RDMA and 10Gig-E uses the least percentage of the available CPU's while 10-GigE uses the most.

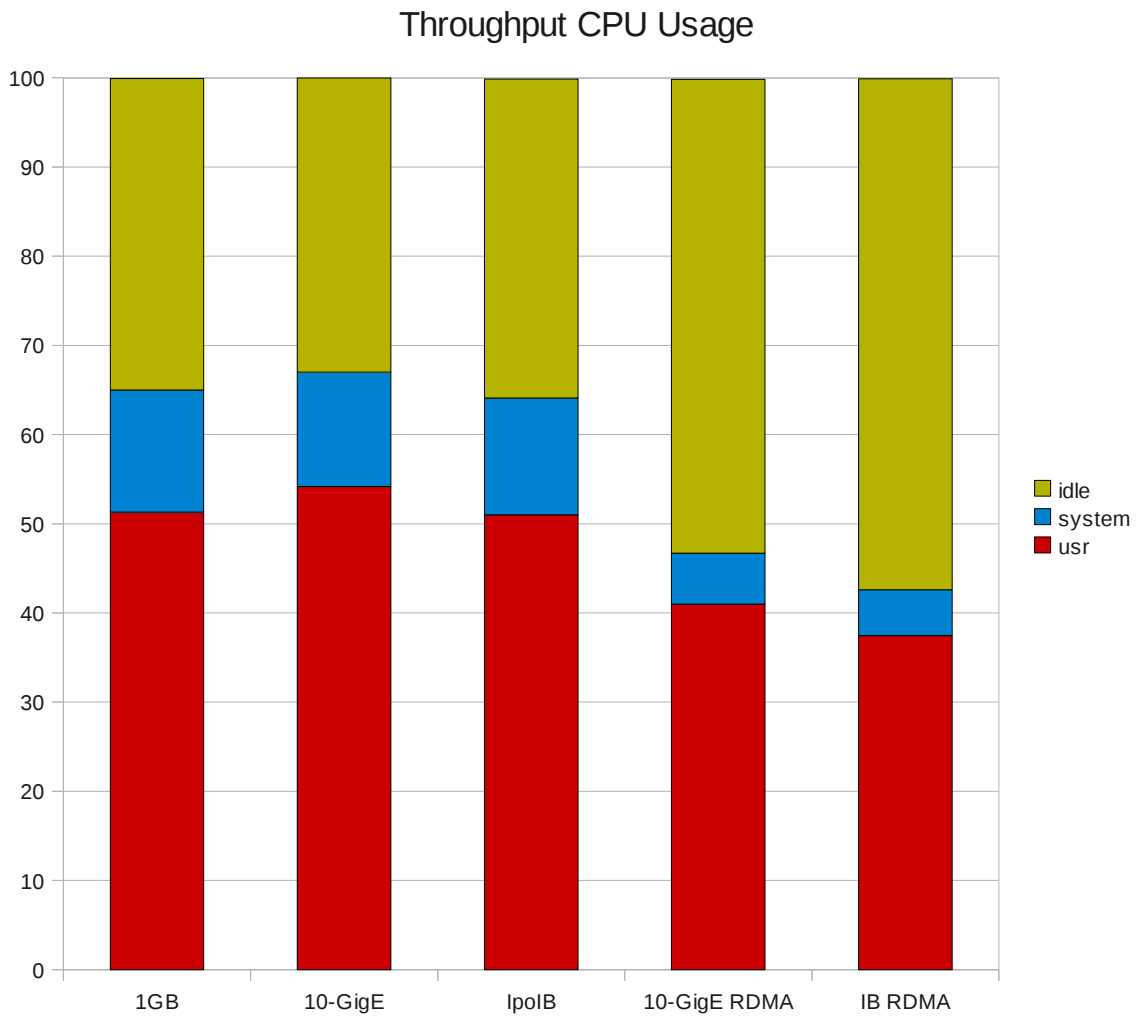


Figure 28

10Gig-E RDMA and IB RDMA processed a significantly larger amount of interrupts than the other protocols while 10 Gig-E had the least.

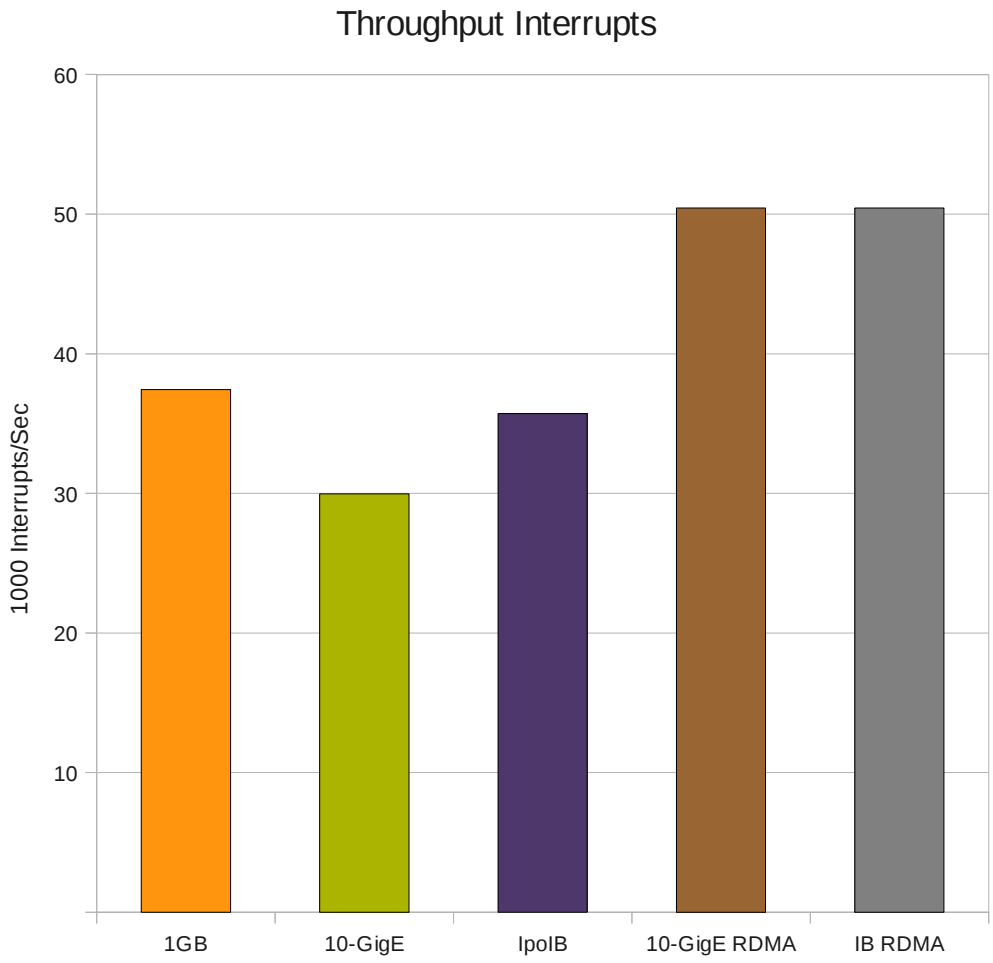


Figure 29

The plotted rate of context switches illustrates that IPoIB was significantly less than the others.

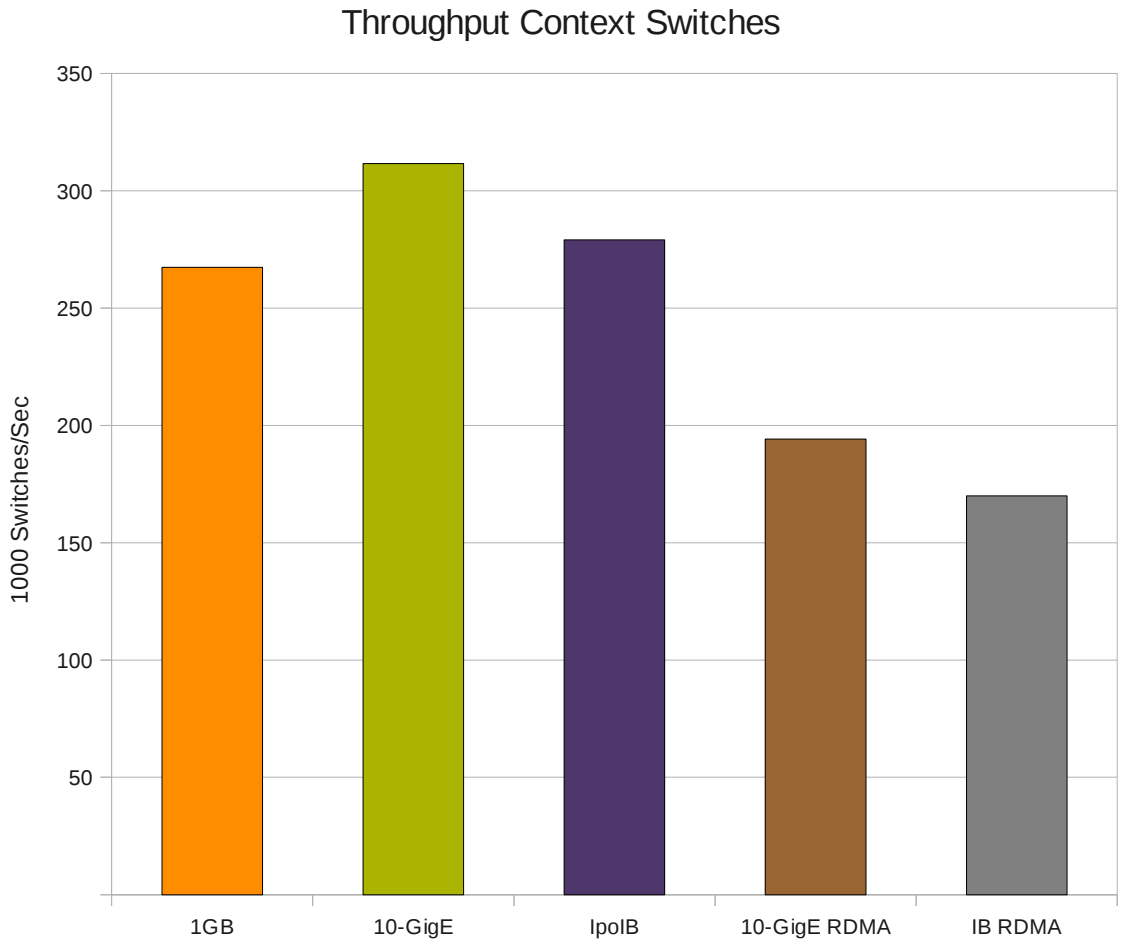


Figure 30

Conclusions

This study demonstrates Red Hat Enterprise Linux 6 High Performance Network Add-on used for Mellonox 10Gbit-E showed running MRG had significant improvement in latency using RDMA over Converged Ethernet (RoCE) compared to Mellonox 10Gbit-IB. Messaging provides a high throughput, low latency messaging infrastructure that can meet the needs of high-performance computing, SOA deployments, and platform services customers.

Furthermore, the reader can use the results to assist in determining configurations which meet their needs. The results show that 10Gig-E provides overall lower-latency and higher throughput than the other interconnects studied. Infiniband 10Gbit is also quite effective, and can be expanded to 20-40 Gbit cards in the future. 1-GigE is a commodity interconnect and could be used for a respectable deployment especially for smaller transfer sizes or with multiple adapters for larger transfers.

Appendix A: Memlock configuration

The default values for memlock limits were too small and generated error messages related to memory. One way to increase the limit is by adding entries to */etc/security/limits.conf* similar to the following.

```
*       hard    memlock unlimited
*       soft    memlock 262144
```