IBM MQ V9.3 for Linux (x86-64 platform) Performance Report

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Notices

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This edition applies to *IBM MQ V9.3* (and to all subsequent releases and modifications until otherwise indicated in new editions).

INTENDED AUDIENCE

This report is intended for architects, systems programmers, analysts and programmers wanting to understand the performance characteristics of IBM MQ V9.3. The information is not intended as the specification of any programming interface that is provided by IBM MQ. It is assumed that the reader is familiar with the concepts and operation of IBM MQ V9.3.

Preface

Target audience

The report is designed for people who:

- Will be designing and implementing solutions using IBM MQ v9.3 for Linux on x86_64.
- Want to understand the performance limits of IBM MQ v9.3 for Linux on x86_64.
- Want to understand what actions may be taken to tune IBM MQ v9.3 for Linux on x86_64.

The reader should have a general awareness of the Linux operating system and of IBM MQ to make best use of this report.

Whilst operating system, and MQ tuning details are given in this report (specific to the workloads presented), a more general consideration of tuning and best practices, with regards to application design, MQ topology etc, is no longer included in the platform performance papers. A separate paper on general performance best practises has been made available here:

https://ibm-messaging.github.io/mqperf/MQ_Performance_Best_Practices_v1.0.1.pdf

Contents

This report includes:

Release highlights with performance charts.

- Performance measurements with figures and tables to present the performance capabilities of IBM MQ, across a range of message sizes, and including distributed queuing scenarios.

V2 Additions (Nov 2023)

- TLS performance moved to section 6 and extended to include persistent messaging results.
- High Availability (HA) results added in section 7).

Feedback

We welcome feedback on this report.

- Does it provide the sort of information you want?
- Do you feel something important is missing?
- Is there too much technical detail, or not enough?
- Could the material be presented in a more useful manner?

Specific queries about performance problems on your IBM MQ system should be directed to your local IBM Representative or Support Centre.

Please direct any feedback on this report to paul_harris@uk.ibm.com.

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TABLES

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1 Introduction

IBM MQ V9.3 is a long-term service (LTS) release of MQ, which includes features made available in the V9.2.1, V9.2.2, V9.2.3, V9.2.4 & V9.2.5 continuous delivery (CD) releases.

Performance data presented in this report does not include release to release comparisons, but all tests run showed equal or better performance than the V9.2 release of IBM MQ.

Note that the tests in this report have been run on hardware significantly newer and more powerful than for the previous V9.2 report. Please bear this in mind should you compare the two reports. For example, the main MQ servers used for the V9.2 and V9.3 reports are:

MQ V9.2 Report

- Lenovo System x3550 M5 – [5463-L2G]
- 2 x 12 core CPUs.
- Core: Intel® Xeon® E5-2690 v3 @ 2.60GHz
- 128GB RAM
- Queue manager recovery log and queue data stored locally 2 x 447GB SSDs (MTFDDAK480MBB) in RAID 0 array, unless otherwise specified.
- 40Gb ethernet adapters connect all three machines via an isolated performance LAN.

MQ V9.3 Report

- ThinkSystem SR630 V2–[7Z71CTO1WW]
- 2 x 16 core CPUs.
  Core: Intel(R) Xeon(R) Gold 6346 CPU @ 3.10GHz
- 256GB RAM
- Queue manager recovery log and queue data stored locally on 2 x 3.2TB NVMe SSDs (KCM61VUL3T20) in RAID 0 array, unless otherwise specified.
- 100Gb ethernet adapters connect all three machines via an isolated performance LAN.

As with all performance sensitive tests, you should run your own tests where possible, to simulate your production environment and circumstances you are catering for.

2 Release Highlights

Release highlights are listed in the MQ 9.3 documentation here:

https://www.ibm.com/docs/en/ibm-mq/9.3?topic=930-whats-new-in-mq

Release highlights are largely functional, but a performance evaluation has been made of the new streaming queues feature.

2.1 Streaming Queues

Streaming queues were introduced in MQ V9.2.3 and allow you to configure a queue to put a near-identical copy of every message to a second queue. One use for streaming queues is to create duplicate messages which will be stored for a short period of time as a contingency measure. In this case the CAPEXPRY custom property is set on the streaming queue to set a time limit on messages. MQ schedules an expiry task run at an interval specified in the mq.ini file (default 5 minutes). This task deletes any messages that are older than the CAPEXPRY value set on it (CAPEXPRY has queue scope, and only affects messages arriving after it has been set, similarly, amending the CAPEXPRY value will only affect subsequent messages).

If the messages on a streaming queue with CAPEXPRY set are not being consumed, then the queue will grow until the expiry task is scheduled and finds messages that are old enough to be deleted. Figure 1 below shows the queue depth of a streaming queue.

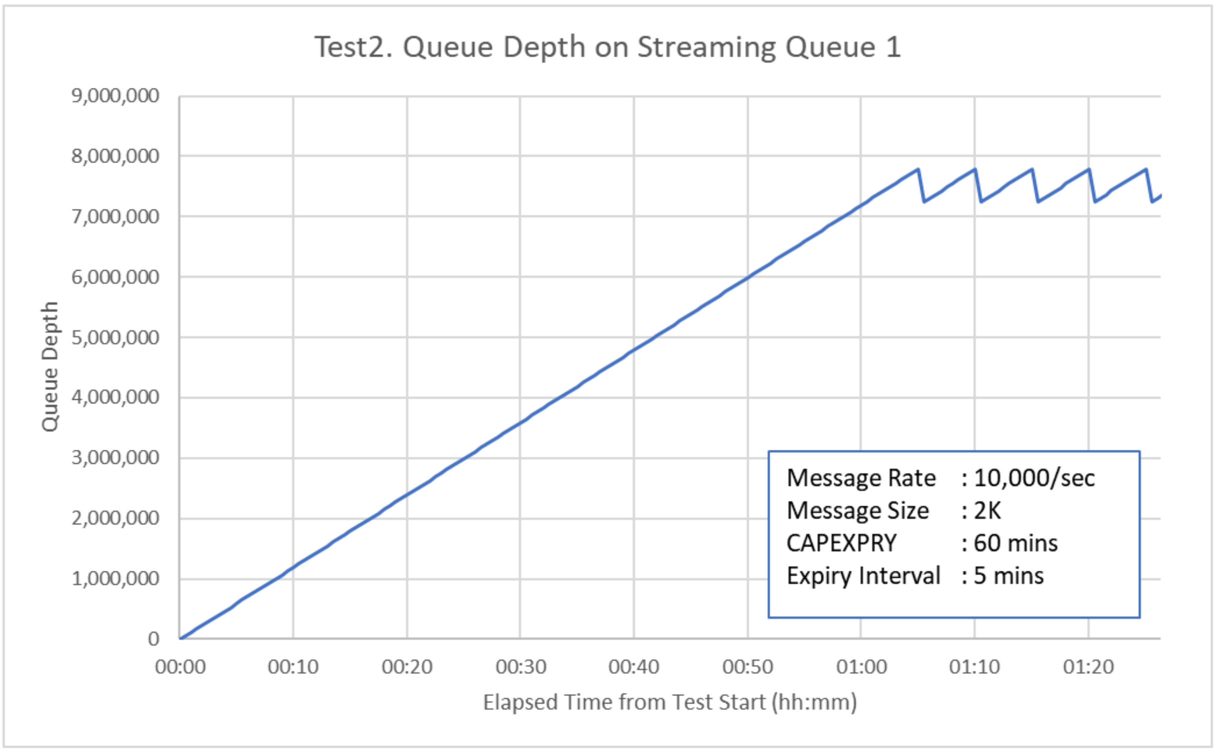


FIGURE 1 : QUEUE DEPTH OF STREAMING QUEUE WITH CAPEXPRY OF 60

In this example, messages are arriving at a rate of 10,000/sec across 5 queues. The plot shows the depth of one of the queues, where CAPEXPRY is set to 60 minutes and ExpiryInterval (the qm.ini file parameter which determines the frequency that the expiry task is scheduled) is set to 5 minutes. In this case the queue grows until the expiry task encounters messages that are 60 minutes or more old. At that point, each time the expiry task is run it will find another 5 minutes' worth of messages that can be deleted, creating the saw-tooth effect above.

When using message expiry with streaming queues you should consider the depth that the queues will grow to and the additional file system storage that may be required.

A more detailed performance report on Streaming Queues was released for V9.2.3 which can be accessed on the MQ performance GitHub page here: MQ V9.2.3 Streaming Queues Performance Report V1.1

3 Base MQ Performance Workloads

Table 1 (below) lists the workloads used in the generation of performance data for base MQ (that is standard messaging function) in this report. All workloads are requester/responder (RR) scenarios which are synchronous in style because the application putting a message on a queue will wait for a response on the reply queue before putting the next message. They typically run 'unrated' (no think time between getting a reply and putting the next message on the request queue).

Workload	Description
RR-CB	Client mode requesters on separate host. Binding mode responders.
RR-DQ-BB	Distributed queueing between two queue managers on separate hosts, with binding mode requesters and responders.
RR-BB	Binding mode requesters and responders
RR-CC	Client mode requesters, and responders on separate, unique hosts

TABLE 1 - WORKLOAD TYPES

Binding mode connections use standard MQ bindings. Client mode connections use fastpath channels and listeners (trusted) and have SHARECNV set to 1, which is the recommended value for performance.

RR-CB & RR-DQ-BB are described in the following section. The remaining two workloads differ only in the location of the MQ applications, which is made clear in the results presented in this report.

Applications, Threads and Processes

From a queue manager's perspective in the workloads described below, each connection represents a unique application. The workloads are driven by the MQ-CPH or Perfharness client emulator tools. Both these tools are multi-threaded so 10 applications may be represented by 10 threads within a single MQ-CPH process, for instance. If 200 responder applications are started, this will always be represented by 200 threads, but they could be spread across 10 processes (each with 20 threads). The main point is that each application below is a single thread of execution within MQ-CPH or JMSPerfHarness, spread across as many processes as makes sense.

3.1 RR-CB Workload

(Client mode requesters on separate host. Binding mode responders.)

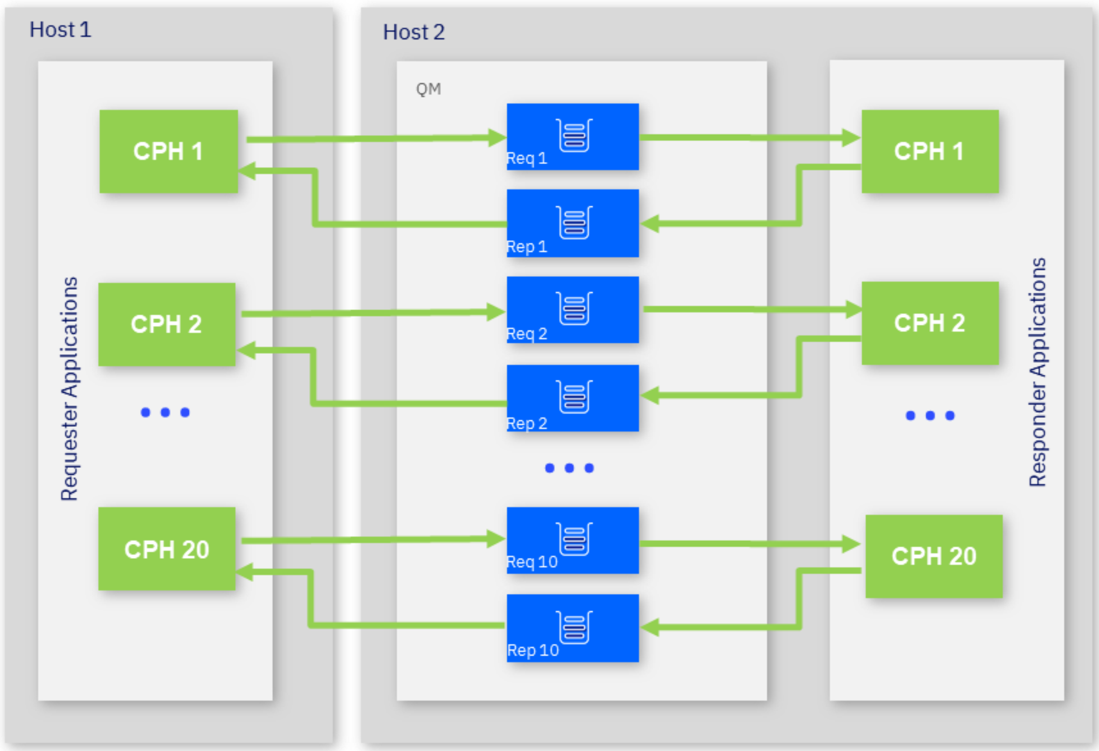


FIGURE 2 - REQUESTER-RESPONDER WITH REMOTE QUEUE MANAGER (LOCAL RESPONDERS)

Figure 2 shows the topology of the RR-CB test. The test simulates multiple 'requester' applications which all put messages onto a set of ten request queues. Additional machines may be used to drive the requester applications where necessary.

Another set of 'responder' applications retrieve the message from the request queue and put a reply of the same length onto a set of ten reply queues. The number of responders is set such that there is always a waiting 'getter' for the request queue.

The applications utilise the requester and responder queues in a round robin fashion, ensuring even distribution of traffic, so that in the diagram above CPH11 will wrap round to use the Rep1/Req1 queues, and CPH 20 will use the Req10/Rep10 queues.

The flow of the test is as follows:

- The requester application puts a message to a request queue on the remote queue manager and holds on to the message identifier returned in the message descriptor. The requester application then waits indefinitely for a reply to arrive on the appropriate reply queue.
- The responder application gets messages from the request queue and places a reply to the appropriate reply queue. The queue manager copies over the message

identifier from the request message to the correlation identifier of the reply message.
- The requester application gets a reply from the reply queue using the message identifier held when the request message was put to the request queue, as the correlation identifier in the message descriptor.

This test is executed using client channels as trusted applications by specifying "*MQIBindType=FASTPATH*" in the qm.ini file. This is recommended generally, but not advised if you run channel exit programs and do not have a high degree of confidence in their robustness.

3.2 RR-BB Workload

(Binding mode requesters with binding mode responders.)

This workload is run the same way as RR-CB above, but with the requesters running in binding mode, on the same host as the queue manager.

3.3 RR-CC Workload

(Client mode requesters with client mode responders.)

This workload is run the same way as RR-CB above, but with the responders running in client mode, on a dedicated, remote host.

3.4 RR-DQ-BB Workload

(Distributed queueing between two queue managers on separate hosts, with binding mode requesters and responders).

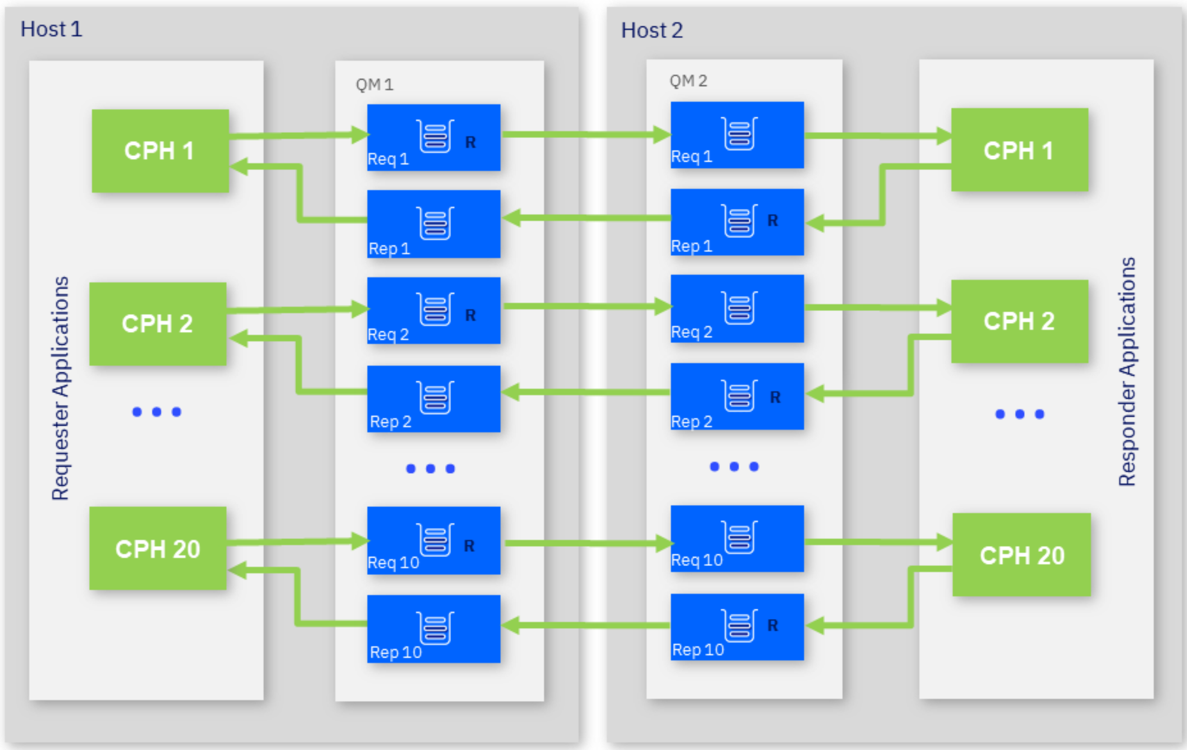


FIGURE 3 - REQUESTER-RESPONDER WITH REMOTE QUEUE MANAGER (REMOTE RESPONDERS).

This is a distributed queuing version of the requester-responder topology detailed in section 3.4. All *MQPUT*s are to remote queues (marked with 'R' in the diagram above), so messages are now transported across server channels to the queue manager where the queue is hosted. Note that remote queues are distributed across multiple pairs of sender/receiver channels in the tests below, but a single pair or channels may be adequate in your installation.

4 Non-Persistent Performance Test Results

Full performance test results are detailed below. The test results are presented by broad categories with an illustrative plot in each section followed by the peak throughput achieved for the remaining tests in that category (the remaining tests are typically for different message sizes).

4.1 RR-CB Workload

The following chart illustrates the performance of 2KB non-persistent messaging with various numbers of requester clients.

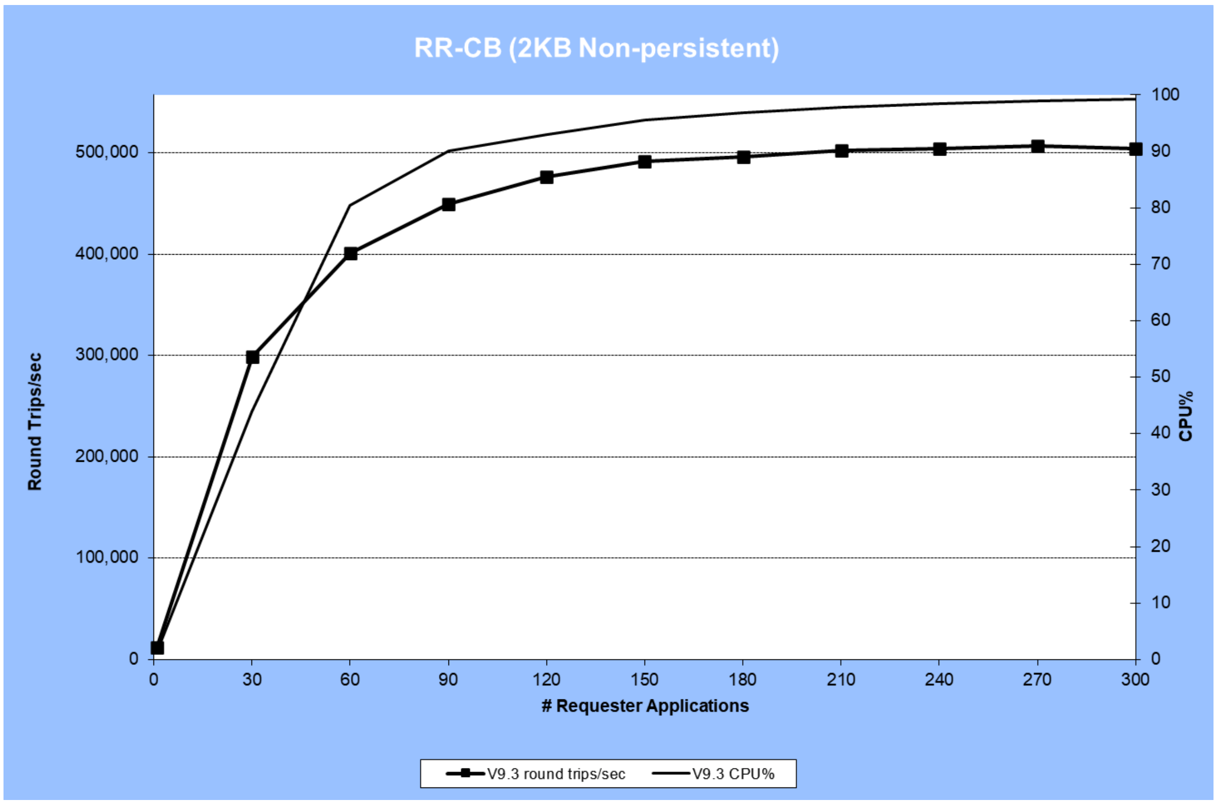


FIGURE 4 - PERFORMANCE RESULTS FOR RR-CB (2KB NON-PERSISTENT)

The test peaked at approximately 500,000 round trips/sec, approaching full CPU utilisation of the MQ server.

Peak round trip rates for all message sizes tested can be seen in the table below. The 200KB and 2MB scenarios are approaching saturation of the 100Gb network links between the client and server machines.

Test	**V9.3**		
	Max Rate*	**CPU%**	**Clients**
RR-CB (2KB Non-persistent)	**506,887**	**98.88**	**270**
RR-CB (20KB Non-persistent)	**332,597**	**95.29**	**150**
RR-CB (200KB Non-persistent)	**52,659**	**43.03**	**100**
RR-CB (2MB Non-persistent)	**5,064**	**35.87**	**45**

Round trips/sec

TABLE 2 - PEAK RATES FOR WORKLOAD RR-CB (NON-PERSISTENT)

4.1.1 Test setup

Workload type: RR-CB (see section 3.1).

Hardware: Server 1, Client 1, Client 2 (see appendix A.1).

4.2 RR-DQ-BB Workload

(Distributed queueing between two queue managers on separate hosts, with binding mode requesters and responders).

The distributed queuing scenarios use workload type RR-DQ-BB (see section 3.4) where locally bound requesters put messages onto a remote queue.

The throughput will be sensitive to network tuning and server channel setup amongst other things. All the tests in this section utilise multiple send/receive channels. This particularly helps with smaller, non-persistent messages when the network is under-utilised.

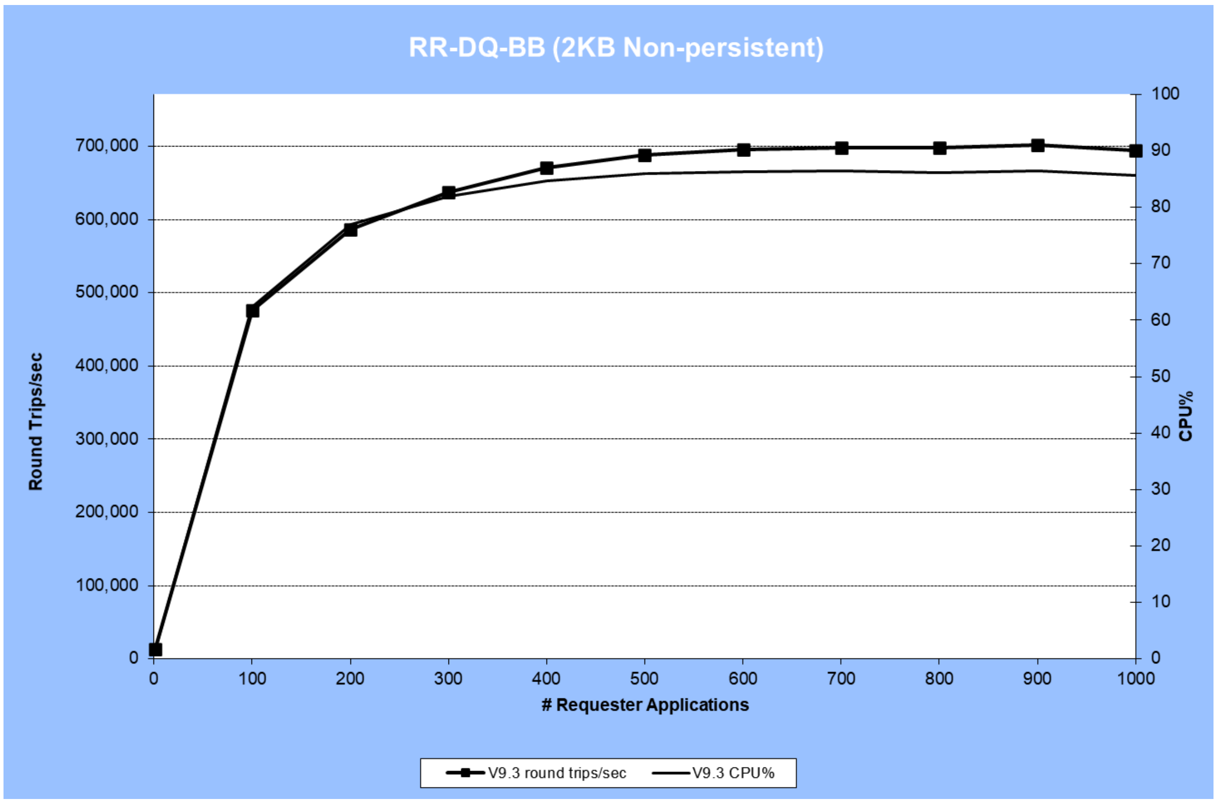


FIGURE 5 - PERFORMANCE RESULTS FOR RR-DQ-BB (2KB NON-PERSISTENT)

The distributed queuing test exhibits good scaling with CPU being the limiting factor as the number of clients increases.

Peak round trip rates for all message sizes tested can be seen in the table below. The 200KB and 2MB measurements are again network limited by the 100Gb links between the hosts.

Test	V9.3		
	Max Rate*	CPU%	Clients
RR-DQ-BB (2KB Non-persistent)	701,776	86.42	900
RR-DQ-BB (20KB Non-persistent)	350,161	61.47	240
RR-DQ-BB (200KB Non-persistent)	57,076	29.42	50
RR-DQ-BB (2MB Non-persistent)	5,497	38.45	40

Round trips/sec

TABLE 3 – FULL RESULTS FOR WORKLOAD RR-DQ-BB (NON-PERSISTENT)

4.2.1 Test setup

Workload type: RR-DQ-BB (see section 3.4).

Hardware: Server 1, Client 1 (see appendix A.1).

4.3 RR-CC JMS Workload

This test application is JMSPerfharness, which is run unrated (i.e. each requester sends a new message as soon as it receives the reply to the previous one). The JMS test is run with both requesters and responders in client mode on remote hosts as JMSPerfharness is a relatively resource hungry application, utilising multiple JVMs to scale up the JMS connections.

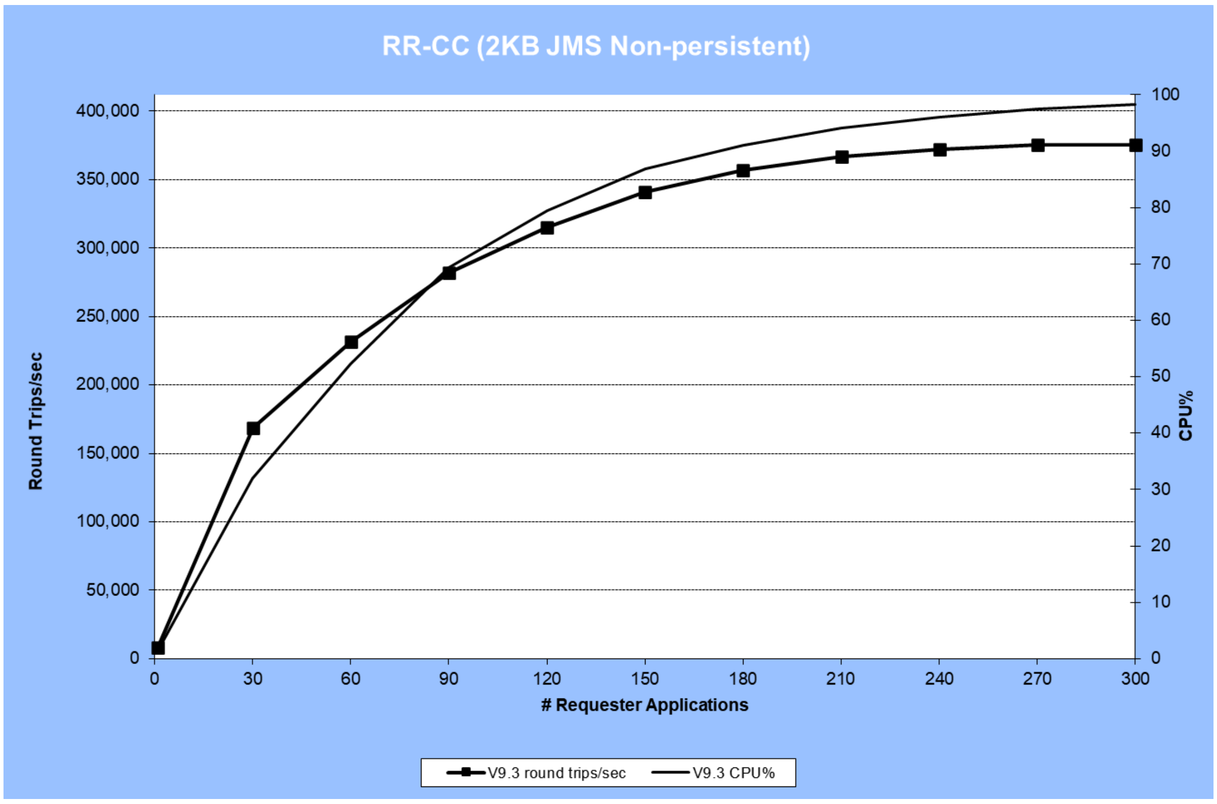


FIGURE 6 - PERFORMANCE RESULTS FOR RR-CC (2KB JMS NON-PERSISTENT)

Once again, the workload exhibits good scaling up to 100% of the CPU (the limiting factor), peaking at approximately 375,000 round trips/sec

Peak round trip rates for all message sizes tested can be seen in the table below. The 200KB and 2MB scenarios are network limited by the 100Gb network; the rates are lower than the RR-CB network limited scenarios because of the additional network hop to the responder applications which are local in the RR-CB scenario.

Test	V9.3 Max Rate*	CPU%	Clients
RR-CC (2KB JMS Non-persistent)	375,453	98.29	300
RR-CC (20KB JMS Non-persistent)	252,003	95.57	240
RR-CC (200KB JMS Non-persistent)	27,580	55.44	200
RR-CC (2MB JMS Non-persistent)	2,653	51.66	200

Round trips/sec

TABLE 4 - PEAK RATES FOR JMS (NON-PERSISTENT)

4.3.1 Test setup

Workload type: RR-CC (see section 3.3).

Message protocol: JMS

Hardware: Server 1, Client 1, Client 2 (see appendix A.1).

5 Persistent Performance Test Results

The performance of persistent messaging is largely dictated by the capabilities of the underlying filesystem hosting the queue files, and more critically, the MQ recovery log files. Writes to the recovery log need to be synchronous to ensure transactional integrity, but IBM MQ is designed to maximise throughput, by aggregating writes where possible. Aggregation of log writes is dependent on a concurrent workload (i.e. multiple applications connected and committing data to the queue manager concurrently, such that the MQ logger component can aggregate data into larger, more efficient file writes and mitigate the higher latency of some file systems).

The performance of persistent messaging is therefore dependant on the machine hosting MQ, the degree of concurrency, *and* the I/O infrastructure. Some comparisons are shown below between non-persistent and persistent messaging for local storage, and then results for V9.3 in a separate environment (x64 Linux with SAN, SSD & NFS filesystems) are shown to demonstrate the impact of recovery log location.

5.1 RR-BB Workload

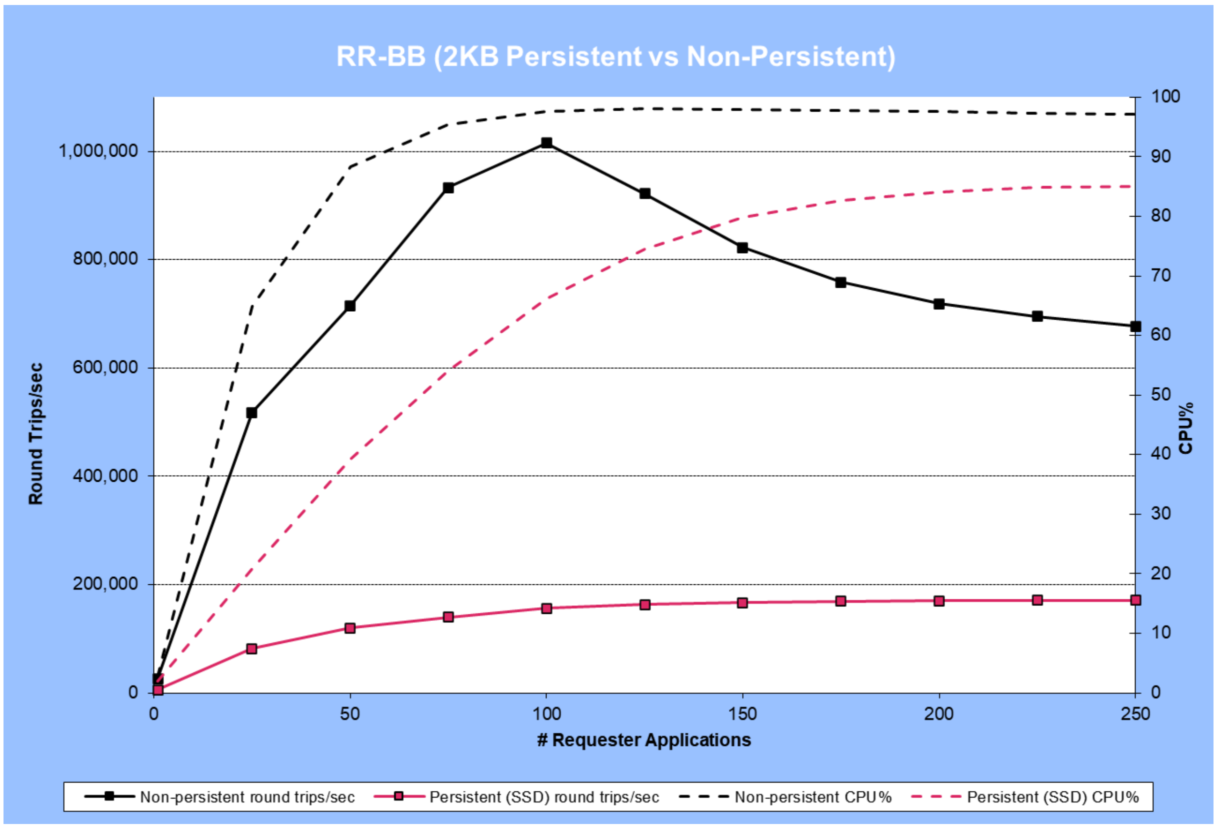


FIGURE 7 - PERFORMANCE RESULTS FOR RR-BB (2KB NON-PERSISTENT VS PERSISTENT)

RR-BB (see section 3.2) is a variant of RR-CB where all applications are connected in bindings mode. This accentuates the impact of persistent messaging since we are no longer limited by network bandwidth.

Figure 7 shows results from running the RR-BB workload with 2KB non-persistent and persistent messages, on the same server used for the non-persistent scenarios in the previous sections.

The non-persistent workload reaches an optimal value at 100 requesters where, the CPU approaches 100% utilisation. Adding more requesters degrades performance, increasing context switching on an already saturated server.

Note that for smaller message sizes (as for 2KB, above), higher rates of throughput in persistent scenarios are attained when there is a greater deal of concurrency (i.e. requester applications) as this enables the logger to perform much larger writes (as described above).

Peak round trip rates for all message sizes tested, for persistent & non-persistent scenarios can be seen in Table 5 & Table 6 below.

Test	**V9.3**		
	Max Rate*	**CPU%**	**Clients**
RR-BB (2K Non-persistent)	**1,034,401**	**97.46**	**96**
RR-BB (20K Non-persistent)	**244,023**	**32.15**	**12**
RR-BB (200K Non-persistent)	**133,707**	**53.33**	**28**
RR-BB (2MB Non-persistent)	**7,296**	**44.86**	**28**

Round trips/ sec

TABLE 5 - PEAK RATES FOR WORKLOAD RR-BB (NON-PERSISTENT)

Test	**V9.3**		
	Max Rate*	**CPU%**	**Clients**
RR-BB (2KB Persistent)	**171,103**	**84.96**	**250**
RR-BB (20KB Persistent)	**109,803**	**60.53**	**175**
RR-BB (200KB Persistent)	**15,030**	**20.93**	**70**
RR-BB (2MB Persistent)	**1,579**	**14.24**	**16**

Round trips/ sec

TABLE 6 - PEAK RATES FOR WORKLOAD RR-BB (PERSISTENT)

With the larger machines used for this report there are limits to these non-persistent workloads before CPU utilisation is the bottleneck. At the highest data transfer rate (200K non-persistent messaging in this case) MQ is transferring data at around 55 GBytes/sec however. Additional queue managers may help though having all applications running locally is not typically representative of the real world. The non-persistent numbers are for comparison with persistent messaging, to illustrate what the impact of logging can be.

The recovery log I/O is the limiting factor for the persistent workloads here, as expected. As the message size goes up, the time spent on the recovery log write becomes a larger factor, so although the bytes per sec is more, the overall CPU utilisation is lower. The level of concurrency needed to reach the limitations of the filesystem also drops as the message size increases.

5.1.1 Test setup

Workload type: RR-BB (see section 3.2).

Hardware: Server 1 (see appendix A.1).

5.2 Impact of Different File Systems on Persistent Messaging Performance

A separate paper has been published, with illustrative results, for SSD, SAN and NFS hosted filesystems, along with some guidance, on best practises, and monitoring.

https://ibm-messaging.github.io/mqperf/mqio_v1.pdf

If possible, you should assess the performance of a new application, with non-persistent messaging first. If the target rate of messaging is met, then calculate the required bandwidth of the filesystem hosting the recovery logs.

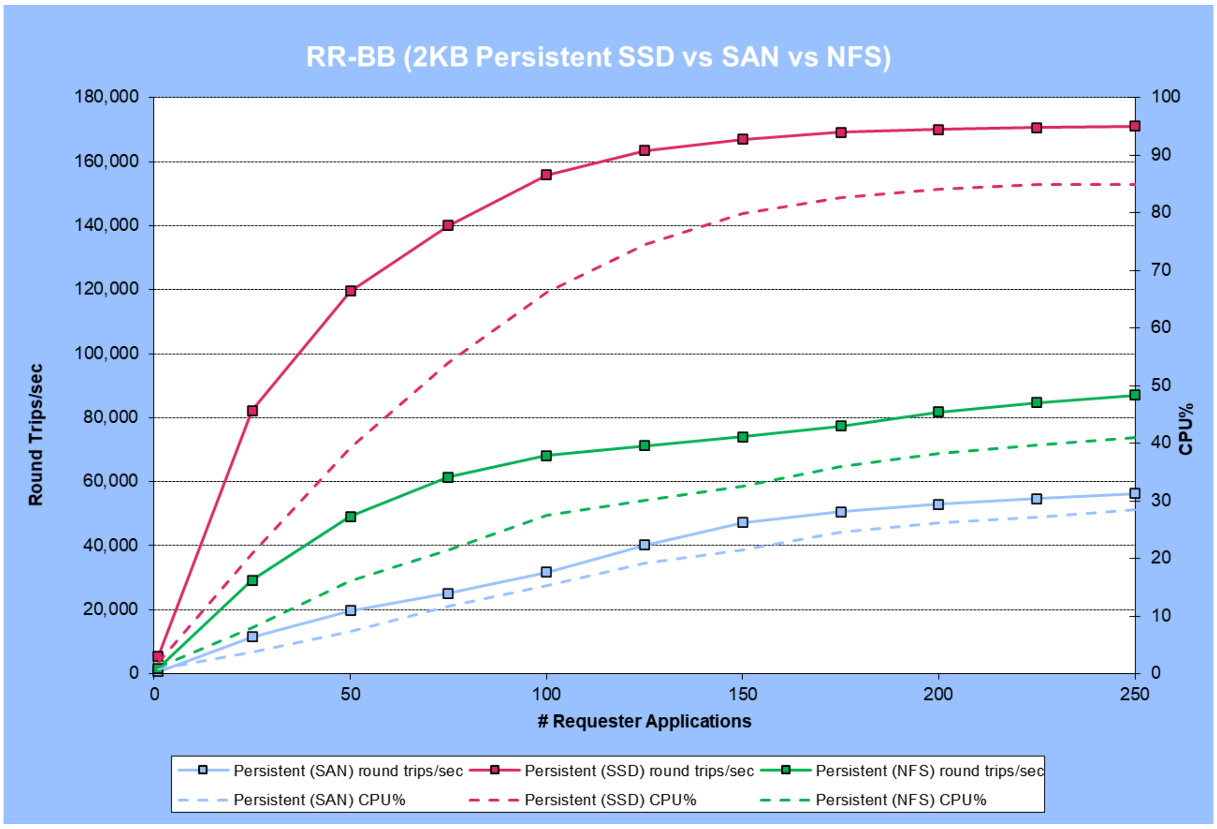


FIGURE 8 - PERFORMANCE RESULTS FOR RR-BB PERSISTENT MESSAGING LOGGING TO SSD, SAN & NFS

To illustrate the impact that the filesystem hosting the recovery logs can have, Figure 8 shows results from running the RR-BB workload with persistent messaging where the recovery logs are on a local SSD or hosted remotely (SAN or NFS).

RR-BB (see section 3.2) is a variant of RR-CB where all applications are connected in bindings mode, eliminating the network traffic (except in the case of NFS, where there is a 100Gb link from the MQ server to the NFS server).

As expected, logging to a local SSD is a lot faster. The SAN tests are limited by the bandwidth of the SAN switch (16Gb ports). For NFS, the network link is 100Gb, but independent tests showed a limit of around 27Gb/s for single threaded transfers (which the MQ logger must by design perform, to maintain data integrity). The MQ logger will perform larger writes as the number of applications increase but there is a 1MB write size for NFS, in the Linux kernel.

Table 7 below, shows the peak rates achieved for each filesystem tested, across a range of message sizes.

Test	V9.3		
	Max Rate*	CPU%	Clients
RR-BB (2KB Persistent - SSD)	171,103	84.96	250
RR-BB (2KB Persistent - SAN)	56,295	28.46	250
RR-BB (2KB Persistent - NFS)	87,082	41.02	250
RR-BB (20KB Persistent - SSD)	109,803	60.53	175
RR-BB (20KB Persistent - SAN)	18,251	13.67	250
RR-BB (20KB Persistent - NFS)	21,894	13.99	250
RR-BB (200KB Persistent - SSD)	15,030	20.93	70
RR-BB (200KB Persistent - SAN)	2,727	5.86	70
RR-BB (200KB Persistent - NFS)	3,048	5.65	70
RR-BB (2MB Persistent - SSD)	1,579	14.24	16
RR-BB (2MB Persistent - SAN)	300	4.11	24
RR-BB (2MB Persistent - NFS)	337	3.76	20

Round trips/ sec

TABLE 7 - PEAK RATES FOR WORKLOAD RR-BB (PERSISTENT SSD VS SAN VS NFS)

5.2.1 Test setup

Workload type: RR-BB (see section 3.2).

Hardware: Server 1, with client 1 machine acting as NFS server. (see appendix A.1).

6 TLS Performance Results

(Client mode requesters and responders on separate hosts).

Note: This section has been updated to include TLS persistent messaging results. All TLS results report here were measured on MQ V9.3.4, the latest generally available release of MQ as of November 2023.

To illustrate the overhead of enabling TLS to encrypt traffic between the client applications and the queue manager, results are shown below comparing the performance of the 6 strongest TLS1.2 MQ CipherSpecs, and all TLS1.3 MQ.

The following TLS 1.2 CipherSpecs were tested (all utilise 256bit encryption and are FIPS compliant).

- TLS_RSA_WITH_AES_256_CBC_SHA256
- TLS_RSA_WITH_AES_256_GCM_SHA384
- ECDHE_ECDSA_AES_256_CBC_SHA384
- ECDHE_ECDSA_AES_256_GCM_SHA384 (Suite B compliant)
- ECDHE_RSA_AES_256_CBC_SHA384
- ECDHE_RSA_AES_256_GCM_SHA384

Results for the suite B compliant CipherSpec (ECDHE_ECDSA_AES_256_GCM_SHA384), along with an older, CBC based CipherSpec (ECDHE_RSA_AES_256_CBC_SHA384) and a TLS 1.3 CipherSpec (TLS_AES_128_CCM_8_SHA256) are plotted below. As will be seen, the remaining tested CipherSpecs exhibited a performance profile similar to one of these plots.

6.1 TLS Non-Persistent Results

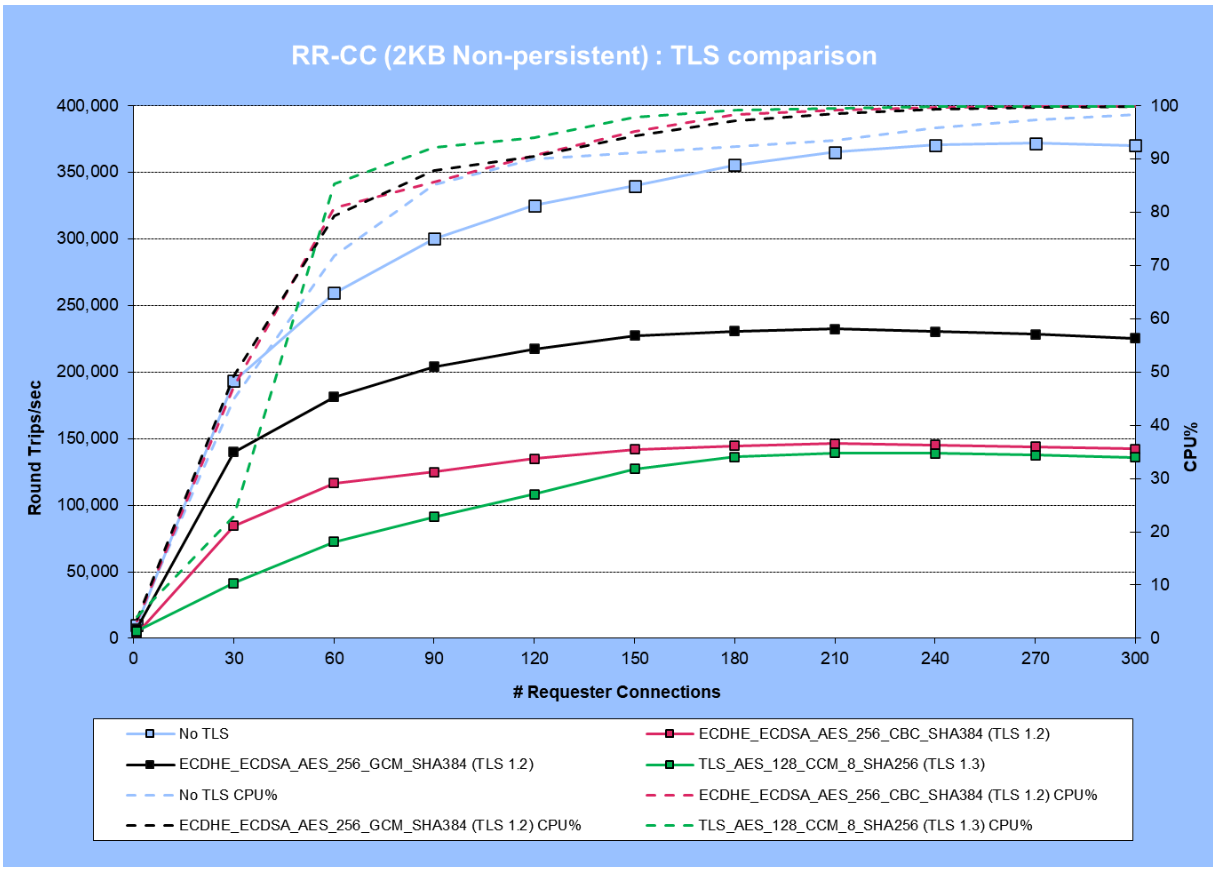


FIGURE 9 - PERFORMANCE RESULTS FOR RR-CC (2KB NON-PERSISTENT) WITH TLS

The ECDHE_ECDSA_AES_256_GCM_SHA384 CipherSpec uses a GCM (Galois/Counter Mode) symmetric cipher. Performance testing showed that all TLS 1.2 GCM based CipherSpecs exhibited similar performance. All of the TLS 1.2 CipherSpecs utilising the older CBC (Chain Block Cipher) symmetric cipher exhibited similar to ECDHE_ECDSA_AES_256_CBC_SHA384 in the plot above. All TLS 1.3 CipherSpecs exhibited a performance profile similar to TLS_AES_128_CCM_8_SHA256 in the plot above.

All tests exhibited scaling up to around 100% of the CPU of the machine. Throughput for GCM based CipherSpecs ran at approximately 62% of the throughput of a non-encrypted workload. CBC based CipherSpecs exhibited a greater overhead, running at approximately 37% of a non-encrypted workload. TLS 1.3 encryption is more expensive, achieving rates slightly below the TLS 1.2 CBC based CipherSpecs.

Table 8 shows the peak rates achieved for all 6 TLS 1.2 CipherSpecs tested, demonstrating the equivalence of performance, based on whether the symmetric key algorithm is CBC, or GCM based.

TLS 1.2 CipherSpec	V9.3 GM Max Rate*	 CPU%	 Clients
No TLS	372,206	97	270
TLS_RSA_WITH_AES_256_CBC_SHA256	164,765	99	210
TLS_RSA_WITH_AES_256_GCM_SHA384	232,673	99	210
ECDHE_ECDSA_AES_256_CBC_SHA384	146,222	99	210
ECDHE_ECDSA_AES_256_GCM_SHA384	232,621	99	210
ECDHE_RSA_AES_256_CBC_SHA384	146,378	99	210
ECDHE_RSA_AES_256_GCM_SHA384	233,483	99	210

Round trips/sec

TABLE 8 - PEAK RATES FOR MQI CLIENT BINDINGS (2KB NON-PERSISTENT) – TLS 1.2

Table 9 shows the peak rates achieved for all TLS 1.3 CipherSpecs.

TLS 1.3 CipherSpec	V9.3 GM Max Rate*	 CPU%	 Clients
No TLS	372,206	97	270
TLS_AES_128_CCM_8_SHA256	139,383	100	210
TLS_AES_256_GCM_SHA384	144,363	100	210
TLS_CHACHA20_POLY1305_SHA256	139,515	100	210
TLS_AES_128_GCM_SHA256	144,911	100	240
TLS_AES_128_CCM_SHA256	128,130	100	300

Round trips/sec

TABLE 9 - PEAK RATES FOR MQI CLIENT BINDINGS (2KB NON-PERSISTENT) – TLS 1.3

6.1.1 Test setup

Workload type: RR-CC (see section 3.3).

Hardware: Server 1, Client 1, Client 2 (see appendix A.1).

6.2 TLS Persistent Results

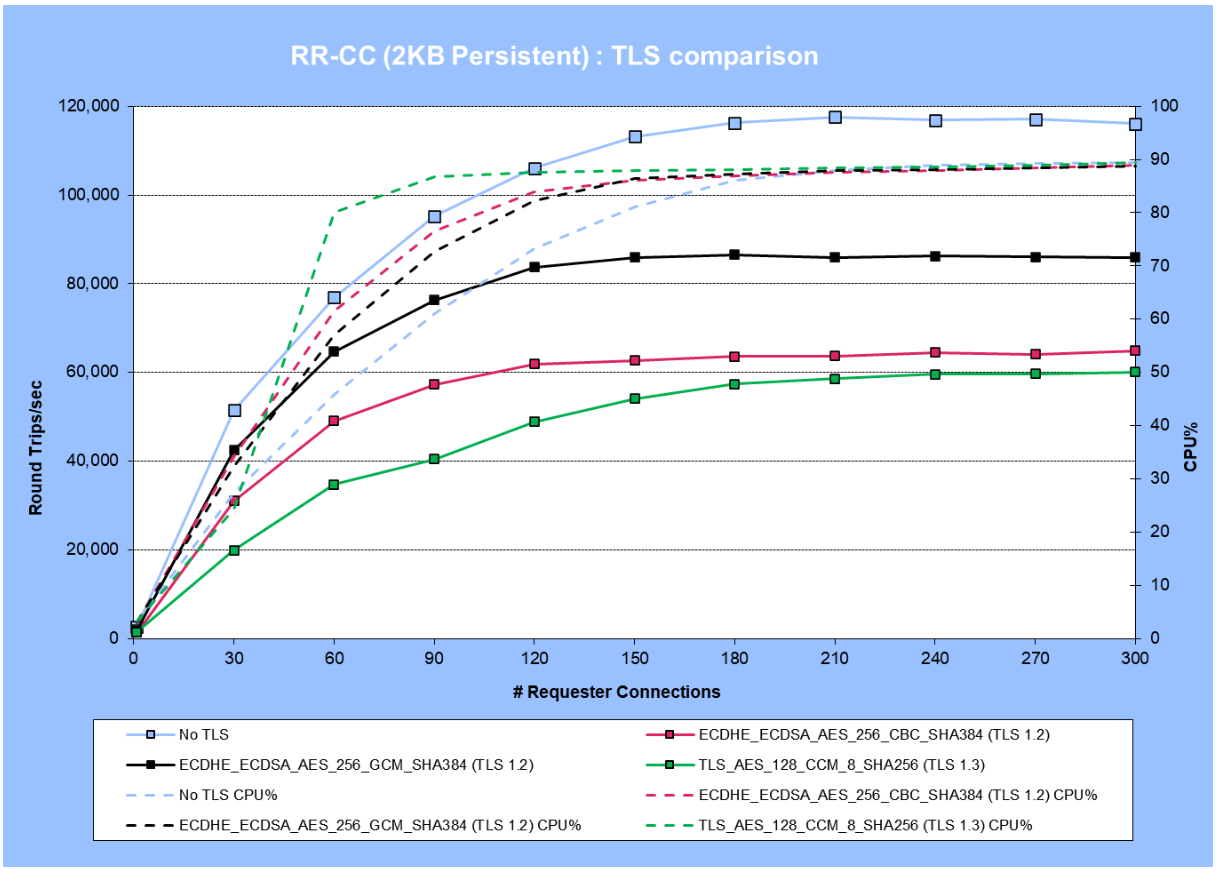


FIGURE 10 - PERFORMANCE RESULTS FOR RR-CC (2KB PERSISTENT) WITH TLS

Generally, the persistent TLS measurements showed a similar pattern to non-persistent tests (though the throughputs were significantly lower throughout, as expected).

Table 10 and Table 11 show the peak throughputs for TLS 1.2 & TLS1.3 CipherSpecs.

TLS 1.2 CipherSpec	V9.3 GM Max Rate*	CPU%	Clients
No TLS	117,544	88	210
TLS_RSA_WITH_AES_256_CBC_SHA256	68,912	89	300
TLS_RSA_WITH_AES_256_GCM_SHA384	86,636	87	180
ECDHE_ECDSA_AES_256_CBC_SHA384	64,892	89	300
ECDHE_ECDSA_AES_256_GCM_SHA384	86,513	87	180
ECDHE_RSA_AES_256_CBC_SHA384	65,332	89	300
ECDHE_RSA_AES_256_GCM_SHA384	87,184	87	180

Round trips/sec

TABLE 10 - PEAK RATES FOR MQI CLIENT BINDINGS (2KB PERSISTENT) – TLS 1.2

TLS 1.3 CipherSpec	V9.3 GM Max Rate*	CPU%	Clients
No TLS	117,544	88	210
TLS_AES_128_CCM_8_SHA256	60,056	89	300
TLS_AES_256_GCM_SHA384	55,641	91	300
TLS_CHACHA20_POLY1305_SHA256	60,471	89	300
TLS_AES_128_GCM_SHA256	62,027	89	300
TLS_AES_128_CCM_SHA256	54,314	91	300

Round trips/sec

TABLE 11 - PEAK RATES FOR MQI CLIENT BINDINGS (2KB PERSISTENT) – TLS 1.3

6.2.1 Test setup

Workload type: RR-CC (see section 3.3).

Hardware: Server 1, Client 1, Client 2 (see appendix A.1).

6.3 Effect of MQ Recovery Log Performance on TLS Comparisons

With persistent messaging, file I/O to the MQ recovery log is a significant throttling factor. This is evident in the TLS persistent messaging results as the ratio between non-TLS and TLS is lower. E.g. for 300 requester clients, non-persistent messaging, this is how a TLS 1.2 and a TLS 1.3 CipherSpec performs, in comparison to a non-TLS workload:

Scenario	**Rate**
No-TLS	370,323
ECDHE_ECDSA_AES_256_GCM_SHA384 (TLS 1.2)	225,441
TLS_AES_128_CCM_8_SHA256 (TLS 1.3)	136,001

Non-persistent ratio (No-TLS/TLS 1.2) = **1.64**

Non-persistent ratio (No-TLS/TLS 1.3) = **2.72**

For persistent messaging the gap is closer:

Scenario	**Rate**
No-TLS	116,051
ECDHE_ECDSA_AES_256_GCM_SHA384 (TLS 1.2)	85,937
TLS_AES_128_CCM_8_SHA256 (TLS 1.3)	60,056

Persistent ratio (No-TLS/TLS 1.2) = **1.35**

Persistent ratio (No-TLS/TLS 1.3) = **1.93**

The persistent tests were run with the MQ recovery logs hosted on local, enterprise class NVMe devices, which are very fast. Hosting the recovery logs off-box will result in lower throughputs for persistent messaging and the comparison between non-TLS and TLS results will be more favourable (in throughput terms) though the CPU cost will be similar.

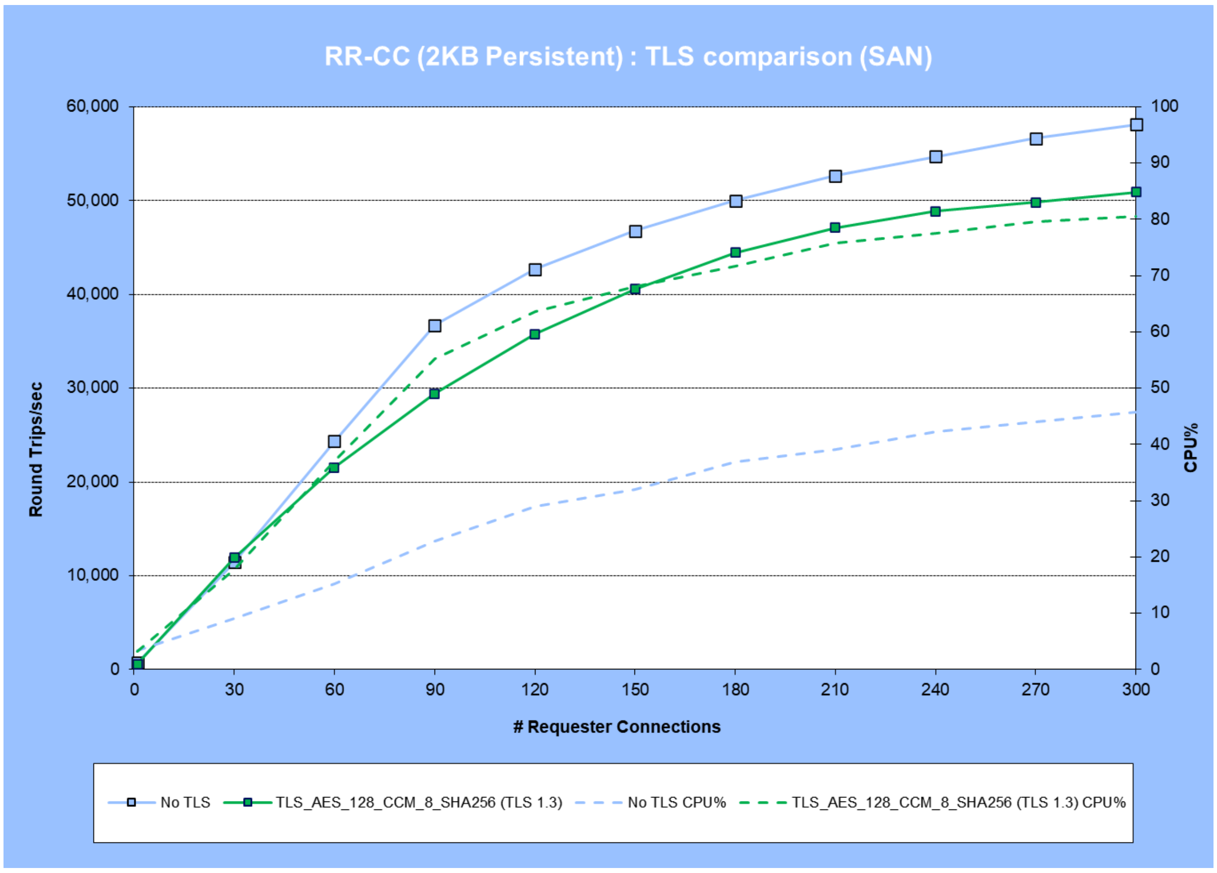


Figure 11 - Performance Results for RR-CC (2KB Persistent) with TLS 1.3 (Logging to SAN)

Figure 11 shows results for the RR-CC workload where the MQ recovery log is hosted on a SAN device (see appendix A.1 for details). In this case the throughputs are lower, as the recovery log file writes to the SAN filesystem are slower. As a result the comparison (in throughput terms) between non-TLS and TLS is more favourable (see below) but note that the CPU overhead remains similar.

Scenario	Rate
No-TLS	58,123
TLS_AES_128_CCM_8_SHA256 (TLS 1.3)	50,905

Persistent ratio (No-TLS/TLS 1.3) = **1.14**

When evaluating TLS, you need to understand the performance capabilities of your infrastructure. Whilst there is a significant CPU cost incurred with encryption, if you have enough capacity the throughput impact may not be as much as the worst case for persistent message, as shown in Figure 10.

As for all performance evaluations, testing an environment as close as possible to that used in production is highly desirable. This will result in a much better understanding of the performance capabilities of the various components making up the environment your workload is running in.

6.3.1 Test setup

Workload type: RR-CC (see section 3.3).

Hardware: Server 1, Client 1, Client 2 (see appendix A.1).

7 High Availability (HA) Test results

This sections is an update to the original report and results here were collected on the latest GA release of MQ (V9.3.4) as of Nov 2023.

There are a number of options available to achieve high availability in MQ, including setting up general high availability managers, or deploying on MQ Appliances (see High availability configurations in the MQ doc).

This section will focus on the two technologies offered in base MQ; Multi Instance Queue Managers (MIQM) and replicated data queue managers (RDQM). For MQ in containers, Native HA (NHA) is another option (and the alternative to using RDQM which is only applicable to non-container deployments).

HA deployments most notably affect the performance of persistent messaging due to the replication of the recovery log writes across the network, so only persistent messaging scenarios are shown in this section. In addition to this, linear logging was used, instead of circular, as this is what NHA uses, and there is little difference in performance (see Figure 12).

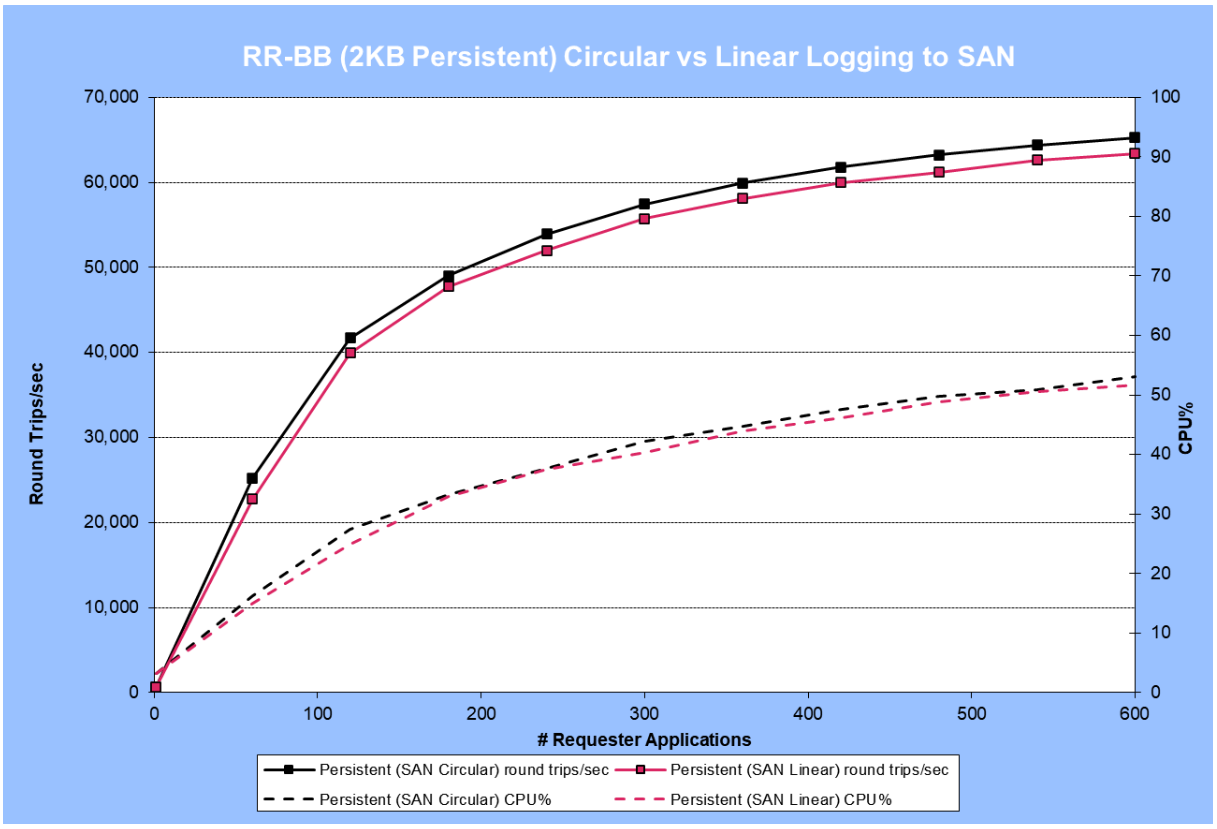


FIGURE 12 - CIRCULAR VS LINEAR LOGGING TO SAN

7.1 RR-CC Workload for HA with Unrestricted Replication Links

Figure 13 shows results for running a 2KB persistent messaging test in an HA setup using MIQM or RDQM, with a SAN test for comparison. Logging to SAN as a comparison is a fairer baseline as this represents a minimal at least a setup where the MQ storage for the queue manager is off-box.

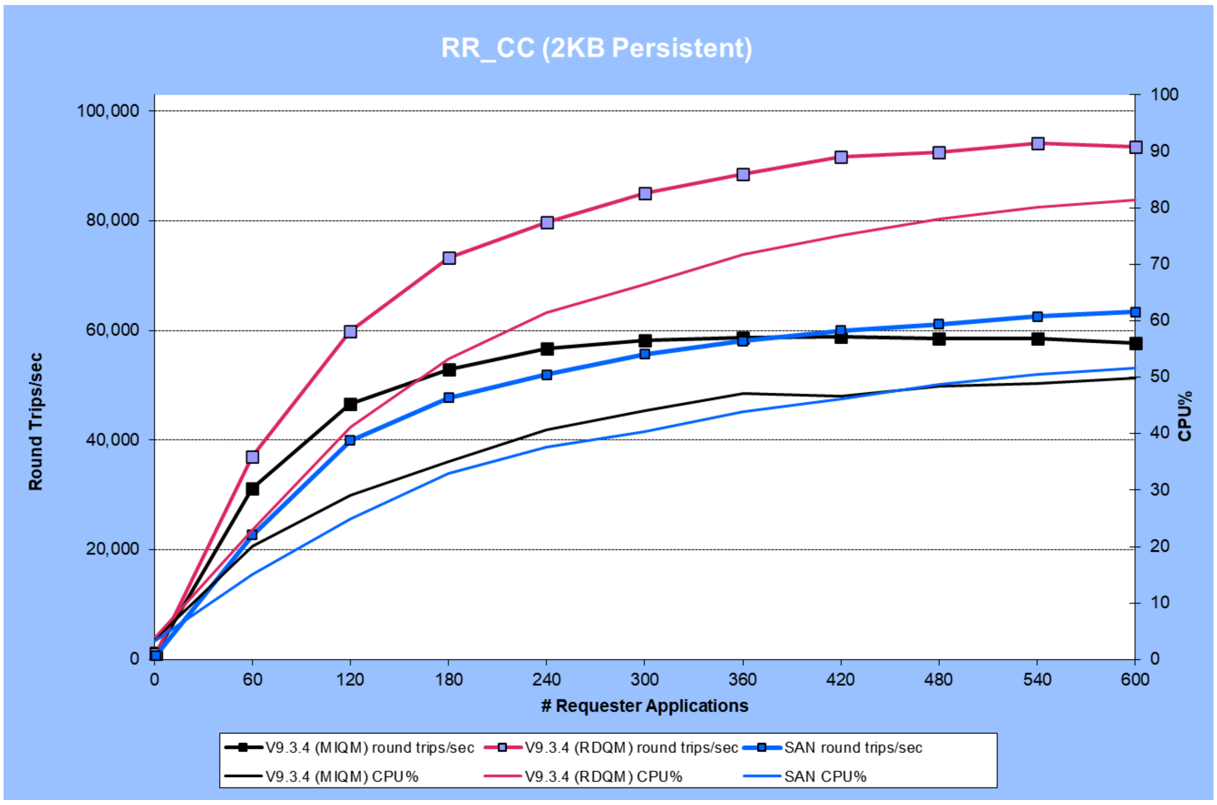


FIGURE 13 - 2KB PERSISTENT HA RESULTS

Care should be taken to review the infrastructure used in these tests. Results reflect the capabilities of the environment. HA persistent test are highly sensitive to the capabilities of the network, and disk storage subsystems. These comparisons are to illustrate the differences that may be seen between different logging/HA approaches.

In the results above, RDQM out-performed the SAN tests , and more significantly also out-performed MIQM. Whilst a faster SAN environment might have resulted in better results, MIQM and RDQM are using the same underlying disk storage and 'replicating' over the same network links (strictly speaking, MIQM is not actually replicating, but simply writing to a remote filesystem over NFS, such that the secondary QM can take-over using the same files, if necessary).

Peak round trip rates for all message sizes tested can be seen in Table 12, with RDQM giving the best performance in all cases.

Test	V9.3.4 (MIQM)			V9.3.4 (RDQM)			V9.3.4 (SAN)		
	Max Rate*	CPU%	Clients	Max Rate*	CPU%	Clients	Max Rate*	CPU%	Clients
RR_CC (2KB Persistent)	58,824	46.64	420	94,137	80.04	540	63,374	51.65	600
RR_CC (20KB Persistent)	13,997	16.18	270	29,762	31.3	300	16,801	17.54	300
RR_CC (200KB Persistent)	1,846	7.55	150	4,098	14.32	150	2,622	7.67	105

Round trips/ sec

TABLE 12 - PEAK RATES FOR WORKLOAD RR-CC (2KB - MIQM/RDQM/SAN)

7.1.1 Test Setup

Workload type: RR-CC (see section 3.3).

Hardware:

SAN Test: Two client machines and a single server with MQ recovery logs hosted on SAN (see appendix section B.1)

MIQM Test: Two client machines, 2 QM hosts and an NFS Server (see appendix section B.2)

RDQM Test: Two client machines and 3 QM hosts (see appendix section B.3)

7.2 RR-CC Workload for HA with 1ms Delay on HA Links

HA solutions involve writing data to a non-local location (whether this the NFS hosted filesystem required by MIQM or by replicating the data across multiple hosts in the case of RDQM). We'll refer to the NFS link or the links between RDQM servers used to replicate the queue and log data as 'HA links'. In our tests these are separate from the links used by the applications on the client machines which were on a separate subnet. Network cards on the test machines can sustain close to the nominal 100Gb duplex bandwidth on both subnets simultaneously (see Appendix B:)

Data written across the HA links is done so in a synchronous fashion to ensure consistency of data in the event of a loss in communication with the active/primary queue manager requiring switchover to the standby/secondary queue manager.

The latency of the HA links will have a direct impact on performance, IBM supports RDQM replication links with latencies up to 5ms (see the doc here), though latencies of that magnitude may be unacceptable to your SLAs. If replication is required across higher latency links then asynchronous replication via a DR solution is preferrable.

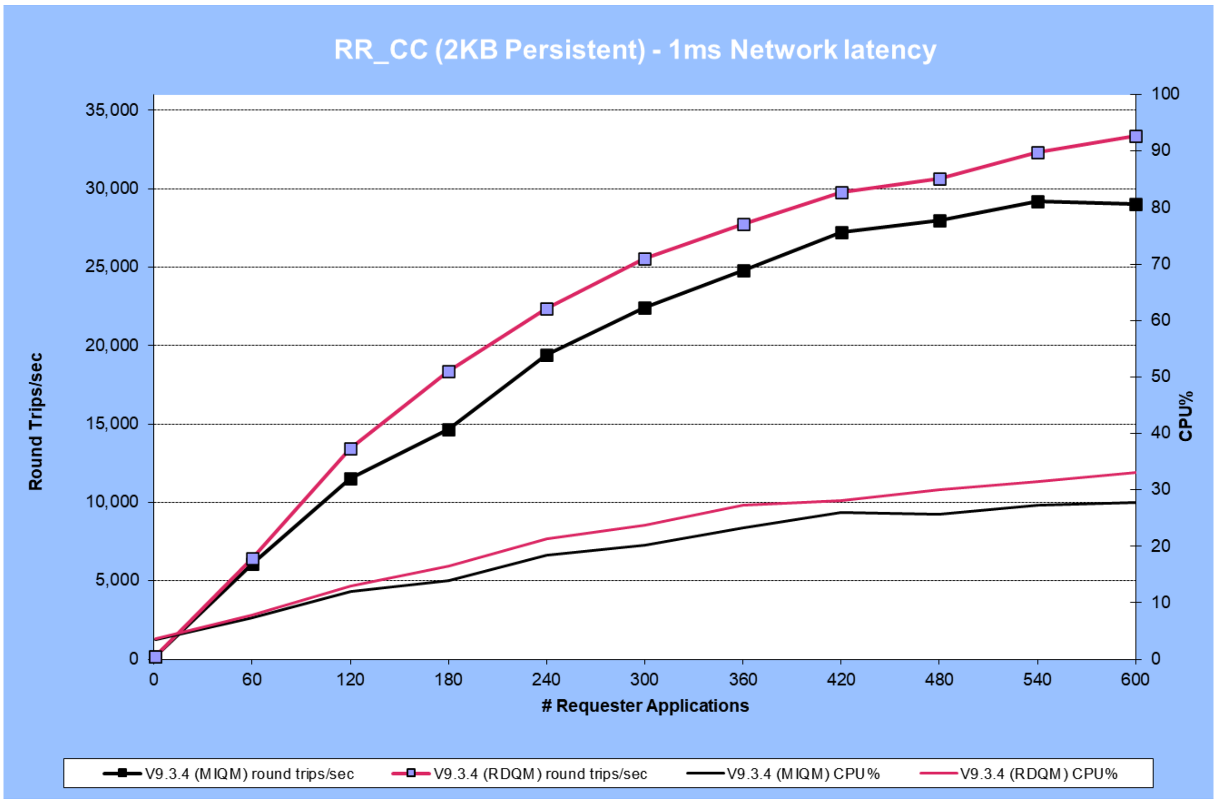


FIGURE 14 - 2KB PERSISTENT HA RESULTS, WITH 1MS NETWORK LATENCY

Figure 14 shows the results of MIQM and SAN tests for 2KB messaging where a delay was set on the HA links only (the separate links to machines hosting the client applications are unhindered). In this case a 500µs delay was set on the inbound and outbound path of the link, resulting in a 1ms round-trip delay. This dramatically reduces the round-trips/sec but still scales in an orderly fashion as more requester applications are started. Writes to the MQ recovery log are typically the limiting factor in persistent messaging and certainly so in this example. The MQ logger will aggregate log writes more as the network latency increases however, minimising the impact of the delay by utilising more of the bandwidth of the link with larger write. You can see the this by monitoring log write sizes using the amqsrua sample program, e.g. on a queue manager called QM1:

```
amqsrua -m QM1 -c DISK -t Log
```

Peak round trip rates for all message sizes tested can be seen in Table 13.

Test	V9.3.4 (MIQM)			V9.3.4 (RDQM)		
	Max Rate*	CPU%	Clients	Max Rate*	CPU%	Clients
RR_CC (2KB Persistent) - 1ms Network latency	29,219	27.27	540	33,366	33.02	600
RR_CC (20KB Persistent) - 1ms Network latency	6,630	9.32	300	8,232	13.39	300
RR_CC (200KB Persistent) - 1ms Network latency	935	4.89	120	1,025	6.71	150

Round trips/ sec

TABLE 13 - PEAK RATES FOR WORKLOAD RR-CC (2KB - MIQM/RDQM WITH 1MS NETWORK LATENCY)

7.2.1 Test Setup

Workload type: RR-CC (see section 3.3).

Hardware:

MIQM Test: Two client machines, 2 QM hosts and an NFS Server (see appendix section B.2)

RDQM Test: Two client machines and 3 QM hosts (see appendix section B.3)

7.3 RR-CC Workload for HA with 2ms Delay on HA Links

This test is similar to the one presented in section 7.2, but with bigger delays set.

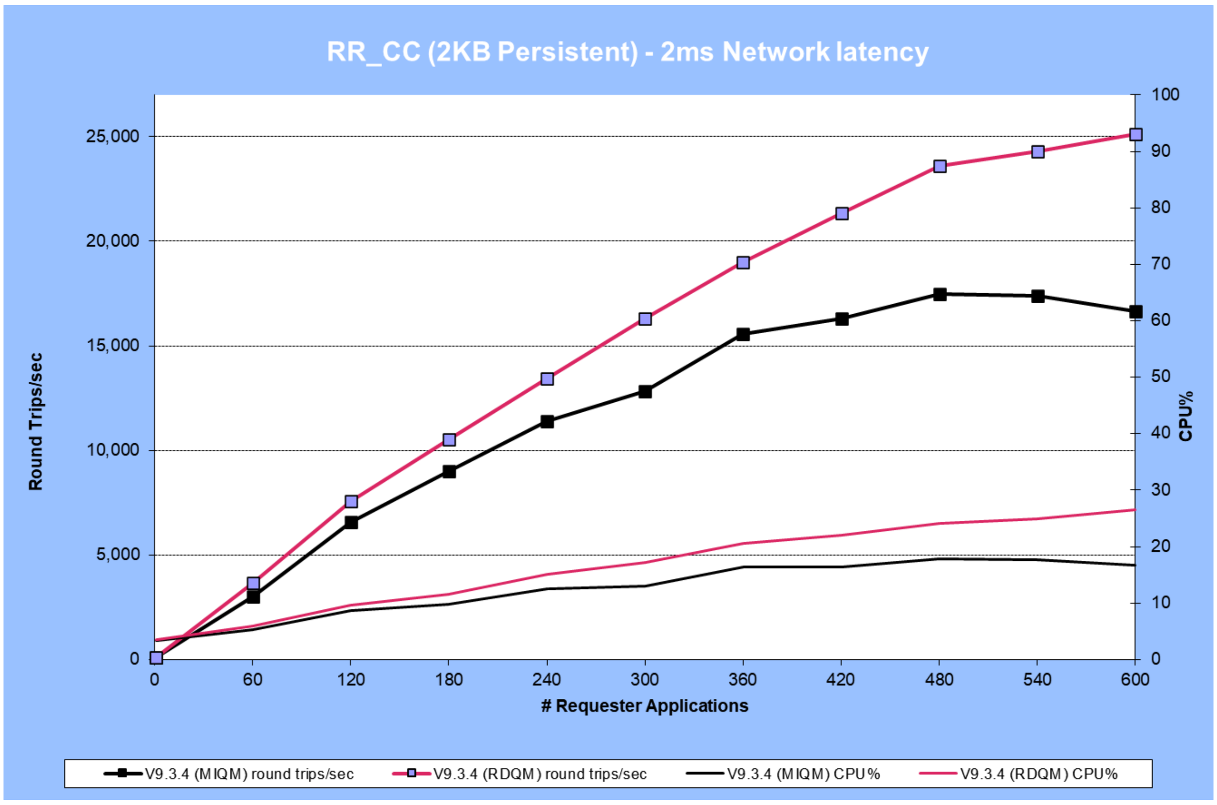


FIGURE 15 - 2KB PERSISTENT HA RESULTS, WITH 2MS NETWORK LATENCY

Figure 15 shows the results of MIQM and SAN tests for 2KB messaging where a delay was set on the HA links only (the separate links to machines hosting the client applications are unhindered). In this case a 1ms delay was set on the inbound and outbound path of the link, resulting in a 2ms round-trip delay. This reduces the round-trips/sec, further but once again scales in an orderly fashion as more requester applications are started.

Peak round trip rates for all message sizes tested can be seen in Table 14.

Test	V9.3.4 (MIQM)			V9.3.4 (RDQM)		
	Max Rate*	CPU%	Clients	Max Rate*	CPU%	Clients
RR_CC (2KB Persistent) - 2ms Network latency	17,490	17.87	480	25,114	26.51	600
RR_CC (20KB Persistent) - 2ms Network latency	4,527	7.06	300	6,934	11.66	300
RR_CC (200KB Persistent) - 2ms Network latency	577	3.25	135	902	5.64	105

Round trips/ sec

TABLE 14 - PEAK RATES FOR WORKLOAD RR-CC (2KB - MIQM/RDQM WITH 2MS NETWORK LATENCY)

7.3.1 Test Setup

Workload type: RR-CC (see section 3.3).

Hardware:

MIQM Test:	Two client machines, 2 QM hosts and an NFS Server (see appendix section B.2)
RDQM Test:	Two client machines and 3 QM hosts (see appendix section B.3)

7.4 Comparison of RDQM HA Results with Different HA Link Latencies.

The previous section showed results for unrestricted HA links and for HA links with 1ms or 2ms round-trip latencies. Figure 16 shows plots for RDQM throughout only, with all three qualities of HA link for a direct comparison. Here the drop in throughput is more obvious when the test is run with a 1ms round-trip latency against a test run without any restriction. In our unrestricted case, the latency of the link is very low, as the network switch resides in the same rack as the hosts it is connecting.

All deployments will be different, so it’s impossible to predict the affect that a higher latency will have. If the network latency of the links between the applications and the queue managers is high for instance, then a higher latency on the HA links may not have such a big effect. As with all performance considerations it’s imperative that you carry out your own tests to assess the infrastructure you intend to deploy on.

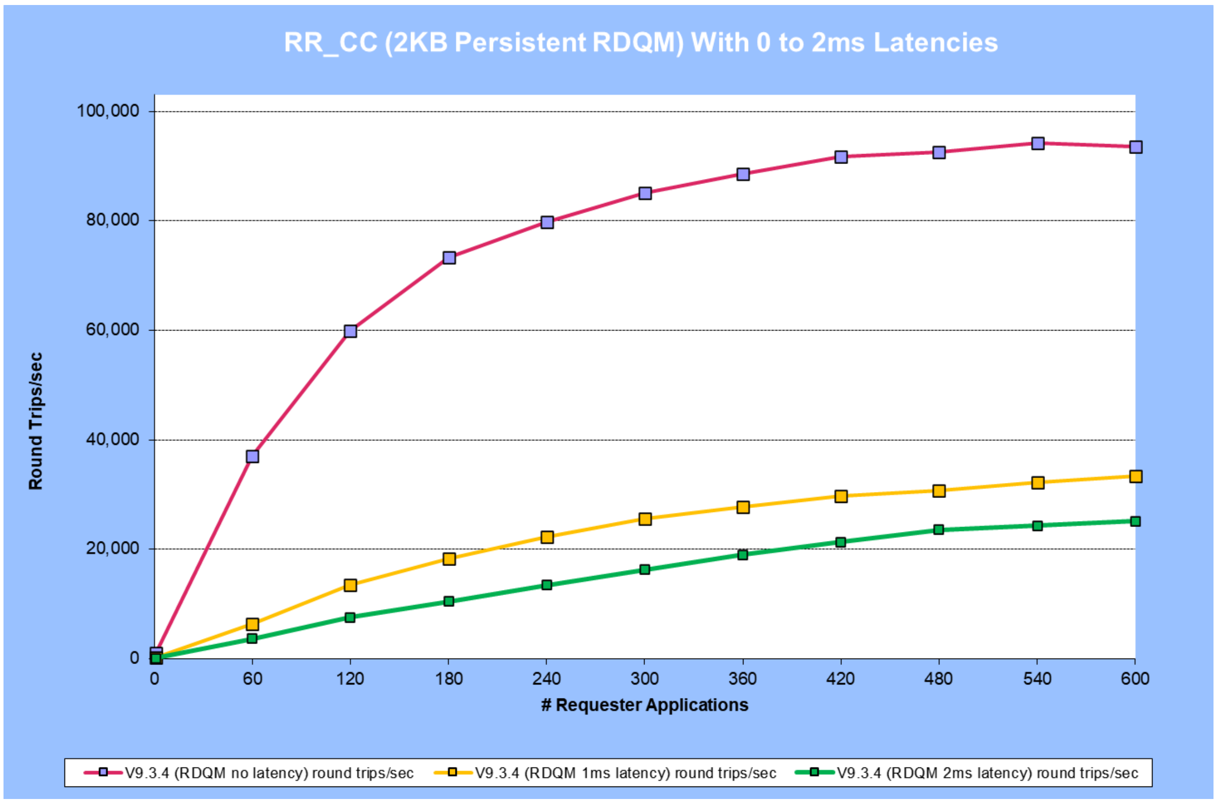


FIGURE 16 - 2KB PERSISTENT HA RESULTS FOR RDQM WITH 0 TO 2MS NETWORK LATENCY

Appendix A: Non-HA Test Configurations

A.1 Hardware/Software – Set1

All the testing in this document (apart from when testing results are shown from a different platform and are clearly identified as such) was performed on the following hardware and software configuration:

A.1.1 Hardware

Server1, client1 & client2 are three identical machines:

- ThinkSystem SR630 V2– [7Z71CTO1WW]
- 2 x 16 core CPUs.
  Core: Intel(R) Xeon(R) Gold 6346 CPU @ 3.10GHz
- 256GB RAM
- Queue manager recovery log and queue data stored locally on 2 x 3.2TB NVMe SSDs (KCM61VUL3T20) in RAID 0 array, unless otherwise specified.
- 100Gb ethernet adapters connect all three machines via an isolated performance LAN.
- Hyper-Threading is enabled but Turbo Boost is disabled. This is to assist with acheiving the best performance that is also consistent.

SAN Infrastructure:

- IBM 2498-F48 fibre channel SAN switch (16Gb/s ports)
- IBM SAN Volume Controller (2145-SV1) with 256GB RAM
- IBM Flash System 900 Storage.

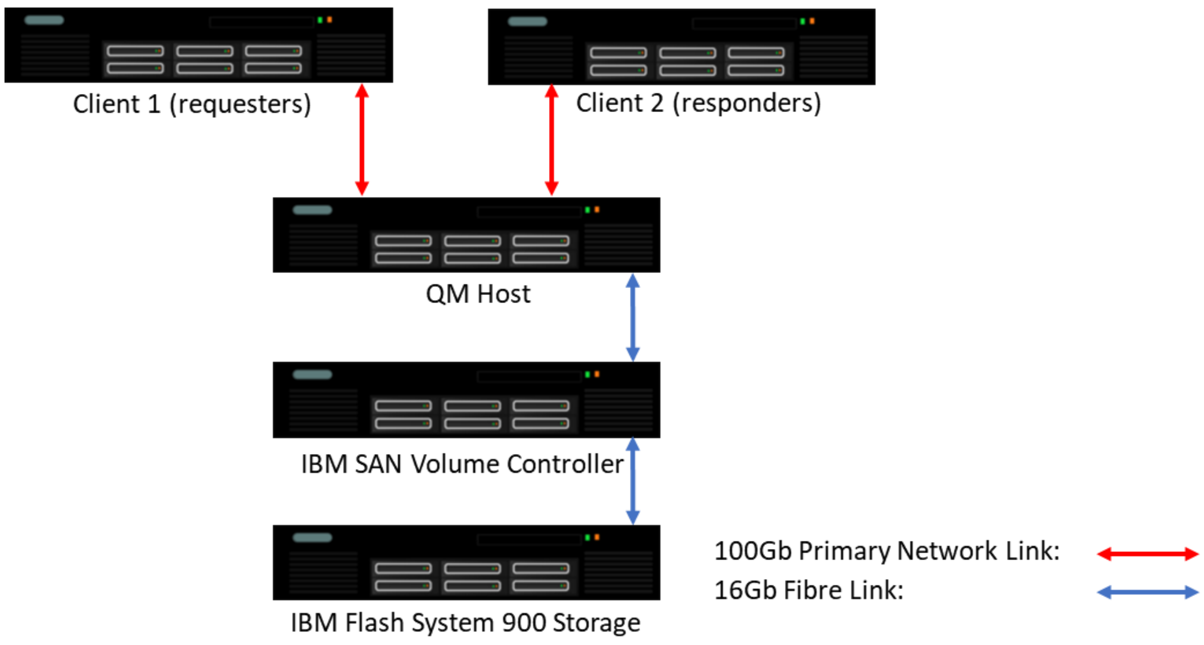
A.1.2 Software

- Red Hat Enterprise Linux Server release 8.5 (Ootpa)
- JMSPerfHarness test driver (see Appendix E:)
- MQ-CPH MQI test driver (see Appendix E:)
- IBM MQ V9.3

Appendix B: HA Test Configurations

B.1 SAN Storage Baseline Topology

The SAN tests used to compare with MIQM and RDQ tests used the following topology.



Client 1 (requesters)
Client 2 (responders)
QM Host
IBM SAN Volume Controller
IBM Flash System 900 Storage
100Gb Primary Network Link:
16Gb Fibre Link:

FIGURE 17 - SAN TEST TOPOLOGY

B.1.1 Hardware

QM Host:

- ThinkSystem SR630 V2– [7Z71CTO1WW]
- 2 x 16 core CPUs.
  Core: Intel(R) Xeon(R) Gold 6346 CPU @ 3.10GHz
- 256GB RAM
- Queue manager recovery log and queue data on SAN.
- 100Gb ethernet adapter on an isolated performance LAN.
- Hyper-Threading is enabled but Turbo Boost is disabled. This is to assist with achieving the best performance that is also consistent.

Client1 & Client2:

- ThinkSystem SR630 - [7X02CTO1WW]
- 2 x 12 core CPUs.
  Core: Intel(R) Xeon(R) Gold 6126 CPU @ 2.60GHz
- 192GB RAM

SAN Infrastructure:

- IBM 2498-F48 fibre channel SAN switch (16Gb/s ports)
- IBM SAN Volume Controller (2145-SV1) with 256GB RAM
- IBM Flash System 900 Storage.

B.1.2 Software

- Red Hat Enterprise Linux Server release 8.5 (Ootpa)
- MQ-CPH MQI test driver (see Appendix E:)
- IBM MQ V9.3.4

B.2 MIQM Topology

For the MIQM tests the file system exported by the NFS server to host the MQ logs and queues, was deployed on 2 x 3.2TB NVMe SSDs (KCM61VUL3T20) in a RAID 0 array. Links between the applications and the MIQM QM hosts were 100Gb on the primary subnet, whilst the NFS links were 100Gb on a separate subnet.

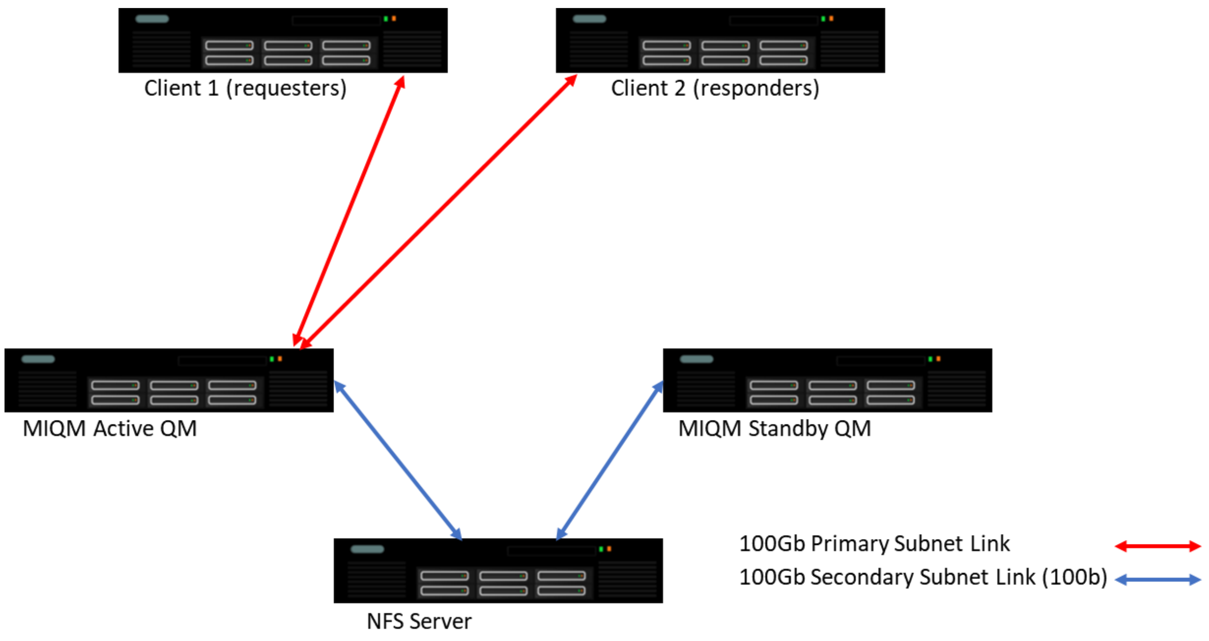


FIGURE 18 - MIQM TEST TOPOLOGY

B.2.1 Hardware

Active/Standby QM hosts and NFS Server:

- ThinkSystem SR630 V2– [7Z71CTO1WW]
- 2 x 16 core CPUs.
  Core: Intel(R) Xeon(R) Gold 6346 CPU @ 3.10GHz
- 256GB RAM
- Queue manager recovery log and queue data on SAN.
- 100Gb ethernet adapter on an isolated performance LAN.
- Hyper-Threading is enabled but Turbo Boost is disabled. This is to assist with achieving the best performance that is also consistent.

Client1 & Client2:

- ThinkSystem SR630 - [7X02CTO1WW]
- 2 x 12 core CPUs.
  Core: Intel(R) Xeon(R) Gold 6126 CPU @ 2.60GHz
- 192GB RAM

B.2.2 Software

- Red Hat Enterprise Linux Server release 8.5 (Ootpa)
- MQ-CPH MQI test driver (see Appendix E:)
- IBM MQ V9.3.4

B.3 RDQM Topology

For RDQM testing, all three RDQM nodes were of type 1 (see machine types, below), and the two application hosts were of type 2. The DRBD volume groups were deployed on 2 x 3.2TB NVMe SSDs (KCM61VUL3T20) in a RAID 0 array. Links between the applications and the RDQM nodes were 100Gb on the primary subnet, whilst the RDQM data replications links were 100Gb on a separate secondary subnet. Each RDQM node had a single Pacemaker address (HA_Primary), utilising the 100Gb link.

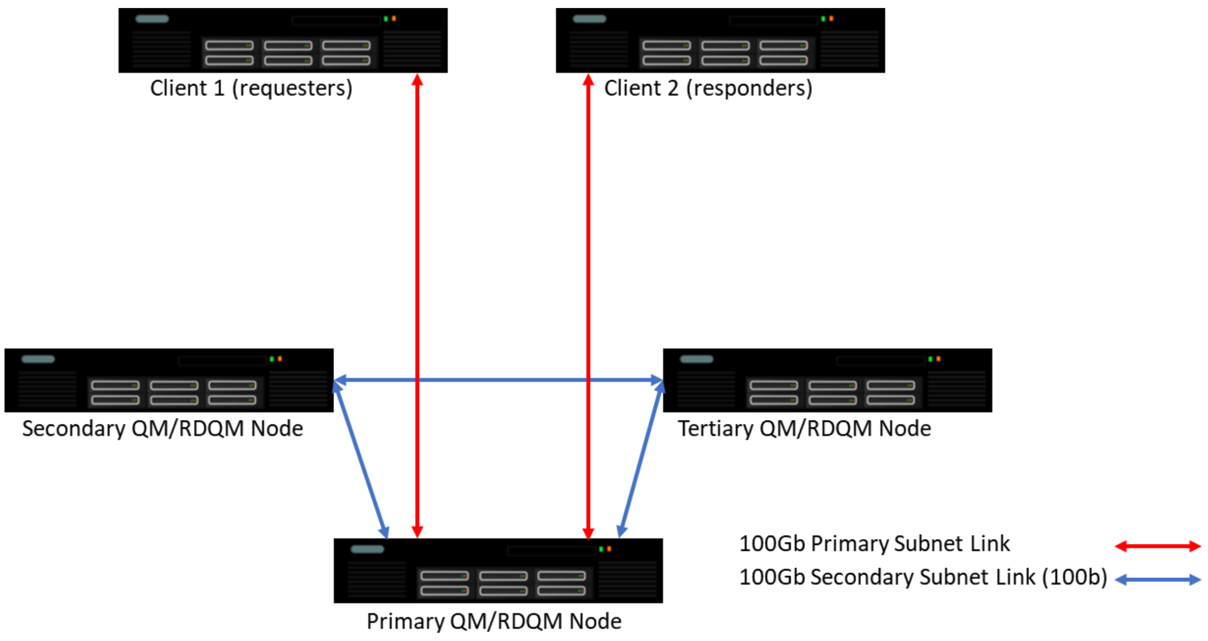


FIGURE 19 - RDQM TEST TOPOLOGY

B.3.1 Hardware

Primary/Secondary/Tertiary QM hosts:

- ThinkSystem SR630 V2– [7Z71CTO1WW]
- 2 x 16 core CPUs.
  Core: Intel(R) Xeon(R) Gold 6346 CPU @ 3.10GHz
- 256GB RAM
- Queue manager recovery log and queue data on SAN.
- 100Gb ethernet adapter on an isolated performance LAN.
- Hyper-Threading is enabled but Turbo Boost is disabled. This is to assist with achieving the best performance that is also consistent.

Client1 & Client2:

- ThinkSystem SR630 - [7X02CTO1WW]
- 2 x 12 core CPUs.
  Core: Intel(R) Xeon(R) Gold 6126 CPU @ 2.60GHz

- 192GB RAM

B.3.2 Software

- Red Hat Enterprise Linux Server release 8.5 (Ootpa)
- MQ-CPH MQI test driver (see Appendix E:)
- IBM MQ V9.3.4

Appendix C: Tuning Parameters Set for Measurements in This Report

The tuning detailed below was set specifically for the tests being run for this performance report but in general follow the best practises.

C.1 Operating System

A good starting point is to run the IBM supplied program mqconfig. The following Linux parameters were set for measurements in this report.

/etc/sysctl.conf

```
fs.file-max = 19557658
net.ipv4.ip_local_port_range = 1024 65535
net.core.rmem_max = 2147483647
net.core.wmem_max = 2147483647
net.ipv4.tcp_rmem = 4096 87380 2147483647
net.ipv4.tcp_wmem = 4096 65536 2147483647
vm.max_map_count = 1966080
kernel.pid_max = 655360
kernel.msgmnb = 131072
kernel.msgmax = 131072
kernel.msgmni = 32768
kernel.shmmni = 8192
kernel.shmall = 18446744073692774399
kernel.shmmax = 18446744073692774399
kernel.sched_latency_ns = 2000000
kernel.sched_min_granularity_ns = 1000000
kernel.sched_wakeup_granularity_ns = 400000
```

/etc/security/limits.d/mqm.conf

```
@mqm soft nofile 1048576
@mqm hard nofile 1048576

@mqm soft nproc  1048576
@mqm hard nproc  1048576
```

```
NFS mount for the MQ recovery log in NFS tests used the following
parameters:
rsize=1048576,wsize=1048576
```

C.2 IBM MQ

The following parameters are added or modified in the qm.ini files for the tests run in section 4 of this report:

```
Channels:
   MQIBindType=FASTPATH
   MaxActiveChannels=5000
   MaxChannels=5000
Log:
   LogBufferPages=4096
   LogFilePages=16384
   LogPrimaryFiles=16
   LogSecondaryFiles=2
   LogType=CIRCULAR
   LogWriteIntegrity=TripleWrite
TuningParameters:
   DefaultPQBufferSize=10485760
   DefaultQBufferSize=10485760
```

For large message sizes (200K & 2MB), the queue buffers were increased further to:

```
DefaultPQBufferSize=104857600
DefaultQBufferSize=104857600
```

Note that large queue buffers may not be needed in your configuration. Writes to the queue files are asynchronous, taking advantage of OS buffering. Large buffers were set in the runs here, as a precaution only.

All client channels were configured with SHARECNV(1), which is the recommendation for performance.

Appendix D: Glossary of terms used in this report

CD	Continuous delivery.
JMSPerfharness	JMS based, performance test application (https://github.com/ot4i/perf-harness)
LTS	Long term service.
MQ-CPH	C based, performance test application (https://github.com/ibm-messaging/mq-cph)

Appendix E: Resources

MQ Performance GitHub Site
https://ibm-messaging.github.io/mqperf/

Streaming Queues Performance Paper
MQ V9.2.3 Streaming Queues Performance Report V1.1

IBM MQ Performance: Best Practises, and Tuning Paper:
https://ibm-messaging.github.io/mqperf/MQ_Performance_Best_Practices_v1.0.1.pdf

MQ-CPH (The IBM MQ C Performance Harness)
https://github.com/ibm-messaging/mq-cph

JMSPerfHarness
https://github.com/ot4i/perf-harness