

MP16: Capacity Planning and Tuning for IBM MQ for z/OS

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Fourth edition, September 2016. This edition applies to IBM MQ for z/OS version 9.0.0 (and to all subsequent releases and modifications until otherwise indicated in new editions).

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This report is intended for Architects, Systems Programmers, Analysts and Programmers wanting to understand the performance characteristics of **IBM MQ for z/OS V9.0 and earlier releases**. The information is not intended as the specification of any programming interfaces that are provided by WebSphere MQ. Full descriptions of the WebSphere MQ facilities are available in the product publications. It is assumed that the reader is familiar with the concepts and operation of IBM MQ.

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Summary of Amendments

Date	Changes
	<p>Version 2.0 is a restructuring of the MP16 SupportPac.</p> <p>Apart from the re-structure, it also includes</p> <ul style="list-style-type: none"> • changes for WebSphere MQ for z/OS version 7.1.0 • performance changes on z196 • disk performance changes using DS8800
2012	<p>A significant amount of costs have been removed from MP16 and can be found in the release specific performance e.g. SupportPac MP1H</p> <p>This document aims to provide guidance on best configuration of the MQ subsystem and how the hardware and software that is used with MQ can affect the performance.</p> <p>It also aims to highlight where limitations may be seen.</p>
2013-April	<p>Version 2.1 includes updates for:</p> <ul style="list-style-type: none"> • WebSphere MQ for z/OS v7.1 support for SSL SHA-2 ciphers.
2015-March	<p>Version 2.2 include updates for:</p> <ul style="list-style-type: none"> • IBM MQ version 8.0 for z/OS • zEnterprise EC12 exploitation • Persistent message rates • 2 versus 3-tier performance
2016-September	<p>Version 2.3 include updates for:</p> <ul style="list-style-type: none"> • IBM MQ for z/OS version 9.0 • LOGLOAD considerations • Queue manager restart • CFCC level 21 • IMS Preload module list • MQ archive logs with zEDC data compression

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Chapter 1

Queue Manager

When installing IBM MQ for z/OS, it is important to consider the following configuration options and decide on the most appropriate definitions for your particular queue manager environment. You should consider these options before customizing the queue manager because it might be difficult to change them once the queue manager has been defined.

The following configuration options should be considered:

- Using appropriate queue manager attributes
- Log data set definitions
- Page set definitions
- Buffer pool definitions
- If you are using shared queues
 - Coupling Facility (CF) structure definitions
 - DB2 table definitions and associated buffer pool and group buffer pool definitions.
 - Shared message data size and usage.

This chapter describes the factors that should be taken into account when designing your queue manager environment.

Queue manager attributes

In a production environment for best performance, it is advisable that both global trace “TRACE(G)” and channel initiator “TRACE(CHINIT)” are disabled unless requested by level 3 Service. For further details of the impact on running with the queue managers global trace enabled, see “[Trace Costs](#)”.

Log data set definition

Before setting up the log data sets, review the following section in order to decide on the most appropriate configuration for your system.

Should your archive logs reside on tape or DASD?

When deciding whether to use tape or DASD for your archive logs, there are a number of factors that you should consider:

- Review your operating procedures before making decisions about tape or disk. For example, if you choose to archive to tape, operators must be available to mount the appropriate tapes when they are required.
- During recovery, archive logs on tape are available as soon as the tape is mounted. If DASD archives have been used, and the data sets migrated to tape using hierarchical storage manager (HSM), there will be a delay while HSM recalls each data set to disk. You can recall the data sets before the archive log is used. However, it is not always possible to predict the order in which they will be required.
- When using archive logs on DASD, if many logs are required (which might be the case when recovering a page set after restoring from a backup) you might require a significant quantity of DASD in order to hold all the archive logs.
- In a low usage system or test system, it might be more convenient to have archive logs on DASD in order to eliminate the need for tape mounts.

How to minimize recovery time

To minimize recovery time and avoid operational complexity it may be best to

- Keep as much recovery log as possible in the active logs on DASD, preferably at least enough for one day.
- Archive straight to tape.
- Page set image copy frequency should typically be at least daily.

Log shunting, introduced by WebSphere MQ version 6.0.0 (see WebSphere MQ for z/OS Concepts and Planning Guide GC34-6582), makes it unlikely that archive logs will be required after a queue manager failure as shunted log records contain sufficient information for transactional recovery.

However, media recovery from a page set or CF application structure failure still requires the queue manager to read all log records since the date and time of the last image copy of that pageset or CF structure backup.

There is some small CPU saving when reading from active versus archive log on disk, but the major objective is to take maximum advantage of available disk space.

The tuning variables are image copy frequency, dualing all image copies to avoid fallback to previous image copy and how much disk space can be made available for the active logs.

Should your installation use single or dual logging?

There is little performance difference between single and dual logging to write-cached DASD unless the total I/O load on your DASD subsystem becomes excessive.

If your DASD type is a physical 3390 or similar, you are advised to use dual logging in order to ensure that you have an alternative backup source in the event of losing a data set, including loss by operator error. You should also use dual BSDSs and dual archiving to ensure adequate provision for data recovery.

If you use devices with in-built data redundancy (for example, Redundant Array of Independent Disks (RAID) devices) you might consider using single active logging. If you use persistent messages, single logging can increase maximum capacity by 6 - 10% and can also improve response times.

If you use dual archive logs on tape, it is typical for one copy to be held locally, and the other copy to be held off-site for use in disaster recovery.

Other reasons for dual logging:

- Software duplexing gives separate names to datasets, which reduces the risk of manual error destroying data, e.g. deleting.
- Different names may map to different storage / management classes so one copy may be local and the other remote.

How many active log data sets do you need?

You should have sufficient active logs to ensure that your system is not impacted in the event of an archive being delayed.

In practice, you should have at least four active log data sets but many customers have enough active logs to be able to keep an entire day's worth of log data in active logs. For example, if the time taken to fill a log is likely to approach the time taken to archive a log during peak load, you should define more logs. You are also recommended to define more logs to offset possible delays in log archiving. If you use archive logs on tape, allow for the time required to mount the tape.

How large can your active logs be?

Prior to MQ version 8.0, when archiving to DASD, the largest single archive dataset supported was 65,535 tracks as IBM MQ does not support splitting an active log to multiple archive datasets on DASD and this is the size limit for data sets accessed with BDAM. This means that the maximum size of an active log is 65,535 tracks, approximately 3.5GB. This limit exists because the size of the log is restricted to the size of the largest archive log that IBM MQ for z/OS is able to access.

From version 8.0, BDAM is no longer used for archive access, so both active and archive logs on DASD may be up to 4GB in size.

If archiving to tape then the largest active log remains at 4GB regardless of MQ release.

Note: When the archive logs are written to DASD and have a primary allocation exceeding 65,535 tracks, (available from version 8.0.0) it may be necessary to ensure the archive data sets are allocated by a DFSMS data class that has a data set name type of LARGE or EXT. LARGE indicates that data sets in the data class are to be allocated in large physical sequential format. EXT indicates that data sets are to be allocated in extended physical sequential format. A setting of EXT is recommended, and is required for striping of data sets. If you specify EXT, also set the IFEXT (if extended) parameter to R (required) rather than P (preferred).

Note: We found that using archive logs of larger than 65,535 tracks resulted in additional CPU cost within the queue manager address space. It is suggested that archive logs larger than 65,535 tracks are only used when the queue manager is likely to be short of active logs. In the event of using these larger archive logs, some additional benefit may be gained by striping across multiple volumes.

How large should the active logs be?

Your logs should be large enough so that it takes at least 30 minutes to fill a single log during the expected peak persistent message load. If you are archiving to tape, you are advised to make the

logs large enough to fill one tape cartridge, or a number of tape cartridges. (For example, a log size of 3GB cylinders on 3390 DASD will fit onto a 3592 tape with space to spare.) When archiving to tape, a copy of the BSDS is also written to the tape. When archiving to DASD, a separate data set is created for the BSDS copy. Do not use hardware compression on the tape drive as this can cause a significant impact when reading the tape backwards during recovery.

If the logs are small (for example, 10 cylinders) it is likely that they will fill up frequently, which could result in performance degradation. In addition, you might find that the large number of archive logs required is difficult to manage.

If the logs are very large, and you are archiving to DASD, you will need a corresponding amount of spare space reserved on DASD for SMS retrieval of migrated archive logs, which might cause space management problems. In addition, the time taken to restart might increase because one or more of the logs has to be read sequentially at start time.

Active log placement

High persistent message throughput typically requires that the active logs are placed on fast DASD with minimum contention from other data set usage. This used to mean there should be no other data set with significant use on the same pack as an active log. With modern RAID DASD the 3390 pack is logical with the physical data spread across multiple disk devices. However, the z/OS UCB (unit control block) for the logical pack may still be a bottleneck. UCB aliasing is available with the z/OS parallel access volumes (PAV) support enabled. You can then have several busy data sets on such a logical pack with good performance for each. This can be exploited to ease any active log placement problems. For instance, you could have the current active log on the same logical pack as the preceding active log. This used to be inappropriate as the preceding log would be read for archive offload purposes while the current active log is being filled. This would have caused contention on a single UCB even to a logical pack.

Where UCB aliases are not available, then ideally, each of the active logs should be allocated on separate, otherwise low-usage DASD volumes. As a minimum, no two adjacent logs should be on the same volume.

When an active log fills, the next log in the ring is used and the previous log data set is copied to the archive data set. If these two active data sets are on the same volume, contention will result, because one data set is read while the other is written. For example, if you have three active logs and use dual logging, you will need six DASD volumes because each log is adjacent to both of the two other logs. Alternatively, if you have four active logs and you want to minimize DASD volume usage, by allocating logs 1 and 3 on one volume and logs 2 and 4 on another, you will require four DASD volumes only.

In addition, you should ensure that primary and secondary logs are on separate physical units. If you use 3390 DASD, be aware that each head disk assembly contains two or more logical volumes. The physical layout of other DASD subsystems should also be taken into account. You should also ensure that no single failure will make both primary and secondary logs inaccessible.

Striped logs

The active logs can be striped using DFSMS. Striping is a technique to improve the performance of data sets that are processed sequentially. Striping is achieved by splitting the data set into segments or stripes and spreading those stripes across multiple volumes. This allows multiple UCBs and this in conjunction with HyperPAV can improve the logging rate achieved with messages larger than 4KB. Messages smaller than 4KB will only write a single 4KB page and will not exploit striping.

Striped archive logs

Prior to IBM MQ version 8.0.0, archive logs used BDAM and as a result could not be striped.

From IBM MQ version 8.0.0, archive logs stored on DASD may be striped. Striping the archive logs may result in an improvement in offload time.

Note: Remember than when moving from non-striped to striped archive logs, it is advisable to divide the PRIQTY and SECQTY values in the CSQ6ARVP macro by the number of stripes otherwise each stripe will be allocated with the specified size e.g.

CSQ6ARVP parameter	No stripes	4 stripes
UNIT	3390	3390
ALCUNIT	CYL	CYL
PRIQTY	5600	1400
SECQTY	100	25

Log data set pre-format

Whenever a new log data set is created it must be formatted to ensure integrity of recovery. This is done automatically by the queue manager, which uses formatting writes on first use of a log data set. This takes significantly longer than the usual writes. To avoid any consequent performance loss during first queue manager use of a log data set, use the log data set formatting utility to pre-format all logs. See the supplied sample job SCSQPROC(CSQ4LFMT).

Up to 50% of maximum data rate is lost on first use of a log data set not pre-formatted on our DASD subsystem. An increase in response time of about 33% with loss of about 25% in throughput through a single threaded application was also observed.

New logs are often used when a system is moved on to the production system or on to a system where performance testing is to be done. Clearly, it is desirable that best log data set performance is available from the start.

Log data set - RAID5 or RAID10

When running tests designed to put persistent messages to the log datasets we have found no discernible difference in performance when using DASD configured as RAID5 over similar tests using DASD configured as RAID10.

8-byte log RBA

From version 8.0, IBM MQ for z/OS improves the availability of the queue manager by increasing the period of time before the log needs to be reset by expanding the size of the log RBA (Relative Byte Address) from 6 to 8 bytes. This increase is such that over 64,000 times as much data can now be written before the log RBA needs to be reset.

In order to support the increased log RBA, additional data is logged. For example a typical request-reply workload using a 1KB request message and a 4KB reply message would need an additional 7% log space over a queue manager using a 6-byte RBA. Were the reply message to be 64KB, the addition space would be 2% compared to a queue manager using a 6-byte log RBA.

How much log space does my message use?

The following tables are provided to give guidance as to the size of logged data for a range of persistent messages. The logged data sizes are an average calculation based on using the process described below. Some additional logging may be seen due to internal queue manager tasks.

These measurements were taken when they were the only workload running against the queue manager. The logcopy dataset was large enough to contain all of the measurements performed. Some additional log writes may be performed when the logcopy file becomes full and the next logcopy dataset is used.

All messages used were persistent and the application specified whether the messages were put or gotten in or out of syncpoint.

How the data was gathered:

- Queue Manager is started.
- DISPLAY LOG issued, note the RBA.
- Perform known workload, e.g. put 10,000 messages to queue.
- DISPLAY LOG issued, again note the RBA.
- Determine how much log data written by change in RBAs.
- Determine logging size per transaction by dividing the delta of the RBA by the known number of transactions performed between DISPLAY LOG commands.

The measurements were run against local and shared queues, for a range of message sizes.

We measured putting and getting from the queues using 3 scenarios:

- 1 message is put or gotten out-of-syncpoint.
- 1 message is put or gotten followed by a MQCMIT.
- 10 messages are put or gotten in-syncpoint following by a MQCMIT. Note, the data in the charts below show the measurements per message put or gotten, so using the data from the Local Queue – Put table, the total size of logged data for the “Put*10, Commit” measurement for a 1 byte message was 751 bytes * 10, i.e. 7510 bytes.

Local Queues

Message Size (bytes)	Log Size in bytes Per message PUT		
	Put out of Syncpoint	Put then Commit	Put*10, Commit
0	1057	1057	751
1	1060	1060	751
1024	2088	2088	1789
4096	5331	5331	5052

Message Size (bytes)	Log Size in bytes Per Message GOT

	Get out of Syncpoint	Get then Commit	Get*10, Commit
0	481	481	186
1	481	481	186
1024	492	492	178
4096	527	527	192

Shared Queues

Message Size (bytes)	Log Size in bytes Per Message PUT		
	Put out of Syncpoint	Put then Commit	Put*10, Commit
0	683	1230	768
1	683	1230	768
1024	1687	2276	1802
4096	4780	5357	4884

Message Size (bytes)	Log Size in bytes Per Message GOT		
	Get out of Syncpoint	Get then Commit	Get*10, Commit
0	62	662	188
1	62	662	188
1024	69	650	177
4096	76	630	185

What is my logging rate?

Consider a requirement where a request/reply application needs to process 1000 transactions per second and the request message is 1KB and the response message is 5KB. The workload is run using local queues.

We can use the above charts to answer a question in the form of bytes per second, i.e.

Application	Action	Size (bytes)
Requester	Put 1KB message out-of-syncpoint	1024 (message) + 1064
Server	Get and commit 1KB	492
Server	Put and commit 5KB	5120 (message) + 1300
Requester	Get 5KB message out-of-syncpoint	550
Total	data logged during transaction	9550

In order to sustain 1000 transactions per seconds, the system needs to log at $1000 * 9550$ bytes per second, **9.11MB/second**.

How much log space do I need when backing up a CF structure?

When backing up a CF structure, the messages on the queues (in the structure) and in the DB2 BLOB tables affect how much is logged. The DISPLAY LOG command can be used to determine how much log space was used as described previously, however the CSQE121I message that is logged following successful completion of structure backup also provides the same information, converted into MB, e.g.:

CSQE121I @QMGR CSQELBK1 Backup of structure APPL1 completed at RBA=00004BFFF8C, size 24 MB

The following table gives guidance as to how much log data is written when the BACKUP CFSTRUCT command is used for a queue of fixed depth but different size messages.

Message size (bytes)	Queue depth	Backup size as reported by CSQE121I (MB)	Size of backup per message (bytes)	Overhead per message (bytes)
0	50,000	24	505	505
1	50,000	24	506	505
1024	50,000	73	1538	514
4096	50,000	219	4642	546

Using the above data as a guide we can predict that 200,000 messages of 4KB in the structure being backup up would use approximately $200,000 * 4642$ bytes, i.e. **855 MB**.

How can we estimate the required log data rate for a system?

The approximate amount of data written to a IBM MQ log for a persistent message that is MQPUT and committed then MQGET and committed is approximately:

Message size (bytes)	MQPUT + MQGET local or client channel	MQPUT + send on message channel with achieved batchsize		Receive on message channel + MQGET with achieved batchsize	
		=1	=50	=1	=50
500	1,700	4,300	1,950	2,750	1,450
1,000	2,300	4,850	2,450	3,300	2,000
5,000	6,550	9,150	6,750	7,600	6,250
10,000	11,750	14,300	11,900	12,800	11,500
30,000	32,800	35,400	33,000	33,900	32,550
100,000	105,800	108,400	106,000	106,900	105,555

Log data rate formulae If required a more detailed estimate may be derived from the following:

User message length + length(all headers) + 1000 bytes
--

Thus, for a 1000 byte persistent message put to and got from a local queue approximately 2300 bytes of data will be written to the IBM MQ log. Using the maximum sustainable DASD data rates given in the section “[Upper bound on persistent messages capacity – DASD log data rate](#)”, for 1000 byte

messages we estimate that up to $32.1 \text{ MB} / 2,300 \text{ bytes} = 14,634$ persistent messages/second can be processed on our DS8800 RAID-5 DASD subsystem; we have achieved this throughput in one measurement scenario with enough concurrent processes, though there was an increased response time. On other DASD subsystems you may get a different maximum.

For long messages the log data requirement is further increased by about 150 bytes per page occupied by the message and all its headers.

For example a 10,000 byte user message requires three 4KB pages.

$10,000 + \text{header length} + 1000 + (3*150) = 11,750$ bytes of data (approximately) will be required on the IBM MQ log for such a message on a local queue.

There is also the following log data requirement for each batch of messages sent or received on a channel (except for batches consisting entirely of non persistent messages on an NPMSPEED(FAST) channel):

- Messages in batch=1
 - Log requires 2.5KB per batch for the sender
 - Log requires 1.3KB per batch for the receiver
- Messages in batch=50
 - Log requires 3.7KB per batch for the sender
 - Log requires 1.3KB per batch for the receiver

If most of your MQPUTs are done at a completely different time to most of your MQGETs then you should be aware that most of the log data is associated with the MQPUT rather than the MQGET. As an example, you may receive messages over channels (MQPUTs) all day and only process those messages (MQGETs) in an overnight batch job.

For throughput estimating purposes assume:

1. For MQGET the log data requirement is about 500 bytes for messages up to a user length of 10 KB. This increases linearly to about 1 300 bytes for messages of user length 100 KB.
2. For MQPUT the actual message, including header data, is placed on the log. To estimate MQPUT requirement calculate
Total log requirement (as above) - MQGET log requirement

NOTE: The above calculations only give throughput estimates. Log activity from other IBM MQ processes can affect actual throughput.

Page sets

When deciding on the most appropriate settings for page set definitions, there are a number of factors that should be considered. These are discussed in the following sections.

Page set usage

In the case of short-lived messages, few pages are normally used on the page set and there is little or no I/O to the data sets except at start time, during a checkpoint, or at shutdown.

In the case of long-lived messages, those buffer pool pages containing messages are normally written out to disk. This is performed by the queue manager in order to reduce restart time.

You should separate short-lived messages from long-lived messages by placing them on different page sets and in different buffer pools.

Size of page sets for a given number of messages

The maximum size of a pageset is:

- 64GB for V6.0.0 and subsequent releases
V6.0 performance for messages on such page sets is the same as that for existing 4GB page sets. Utility performance is also unchanged per GB processed.
- 4GB for prior releases

The number of messages fitting into a page set is approximately as shown in the following charts when using a version 6.0 or version 7.0.1 and subsequent release queue managers, assuming all messages are the same size.

Pages per message	Message size (user data plus all headers except MQMD)			Approx msgs per 4GB pageset	Approx msgs per 64GB pageset
	V6	V7.0.1 onwards as shipped	V7.0.1 onwards maxshortmsgs 0		
8	27992 - 32040	27924 - 31971	27924 - 31971	125K	2M
7	23942 - 27991	23876 - 27923	23876 - 27923	142K	2285K
6	19894 - 23941	19828 - 23875	19828 - 23875	166K	2666K
5	15845 - 19893	15780 - 19827	15780 - 19827	200K	3200K
4	11796 - 15844	11732 - 15779	11732 - 15779	250K	4M
3	7747 - 11795	7684 - 11731	7684 - 11731	333K	5333K
2	3698 - 7746	3636 - 7683	3636 - 7683	500K	8M
Messages per page					
1	1656 - 3697	0 - 3635	1568 - 3635	1M	16M
2	981 - 1655	N/A	892 - 1567	2M	32M
3	643 - 980	N/A	554 - 891	3M	48M
4	440 - 642	N/A	351 - 553	4M	64M
5	305 - 439	N/A	216 - 350	5M	80M
6	208 - 304	N/A	119 - 215	6M	96M
7	136 - 207	N/A	47 - 118	7M	112M
8	79 - 135	N/A	0 - 46	8M	128M
9	34 - 78	N/A	N/A	9M	144M
10	0 - 33	N/A	N/A	10M	160M

Version 7.0.1 changed the manner in which short messages are stored. Refer to “[Why WebSphere MQ for z/OS changed the way it stored small messages in V7.0.1.](#)” for the reasons for this change. Performance report [MP1G](#) discusses the “MAXSHORTMSGS” tuning option which allows the user to revert to version 7.0.0 and earlier behaviour.

You should allow enough space in your page sets for the expected peak message capacity. You should also specify a secondary extent to allow for any unexpected peak capacity, such as when a build up of messages develops because a queue server program is not running.

NOTE: Prior to V6.0.0 the application that causes page set expansion will have to wait until the expansion has completed. This can be many seconds depending on the secondary extent size.

With V6.0.0 a page set that is allowed to expand will begin expansion when the 90% full threshold is passed. While expansion is in progress each MQPUT to it will be delayed by a few milliseconds. This means that it is less likely that an application needing to exploit a large page set will receive a 2192 (media full) return code.

Where DASD space allows, initial allocation of the largest possible page set remains the best option to minimize the possibility of an application stopping for media full reasons.

Number of page sets

Using several large page sets can make the role of the IBM MQ administrator easier because it

means that you need fewer page sets, making the mapping of queues to page sets simpler.

Using multiple, smaller page sets has a number of advantages. For example, they take less time to back up and I/O can be carried out in parallel during backup and restart. However, consider that this adds a significant overhead to the role of the IBM MQ administrator, who will be required to map each queue to one of a much greater number of page sets.

The time to recover a page set depends on:

- The size of the page set because a large page set takes longer to restore.
- The time the queue manager takes to process the log records written since the backup was taken; this is determined by the backup frequency and the amount of persistent log data (to all queues on all page sets) required to be read and processed.

Recovering page sets

A key factor in recovery strategy concerns the period of time for which you can tolerate a queue manager outage. The total outage time might include the time taken to recover a page set from a backup, or to restart the queue manager after an abnormal termination. Factors affecting restart time include how frequently you back up your page sets, and how much data is written to the log between checkpoints.

In order to minimize the restart time after an abnormal termination, keep units of work short so that, at most, two active logs are used when the system restarts. For example, if you are designing an IBM MQ application, avoid placing an MQGET call that has a long wait interval between the first in-syncpoint MQI call and the commit point because this might result in a unit of work that has a long duration. Another common causes of long units of work is batch intervals of more than 5 minutes for the mover.

You can use the DISPLAY CONN command to display the RBA of units of work and to help resolve the old ones. For information about the DISPLAY CONN command, see the IBM MQ Script Command (MQSC) Reference manual.

How often should a page set be backed up?

Frequent page set backup is essential if a reasonably short recovery time is required. This applies even when a page set is very small or there is a small amount of activity on queues in that page set.

If you use persistent messages in a page set, the backup frequency should be in the order of hours rather than days. This is also the case for page set zero.

In order to calculate an approximate backup frequency, start by determining the target total recovery time. This will consist of:

- The time taken to react to the problem.
- The time taken to restore the page set backup copy. For example, we can restore approximately 6200 cylinders of 3390 data per minute from and to DS8800 DASD using DFDSS. Using REPRO, the rate was 3700 cylinders per minute.
- The time the queue manager requires to restart, including the additional time needed to recover the page set.

This depends most significantly on the amount of log data that must be read from active and archive logs since that page set was last backed up. All such log data must be read, in addition to that directly associated with the damaged page set. When using fuzzy backup, it might be

necessary to read up to three additional checkpoints, and this might result in the need to read one or more additional logs.

When deciding on how long to allow for the recovery of the page set, the factors you need to consider are:

- The rate at which data is written to the active logs during normal processing:
 - The amount of data required on the log for a persistent message is approximately 1.3 KB more than the user message length.
 - Approximately 2.5 KB of data is required on the log for each batch of non fast messages sent on a channel.
 - Approximately 1.4 KB of data is required on the log for each batch of non fast messages received on a channel.
 - Non-persistent messages require no log data. NPMSPEED(FAST) channels require no log data for batches consisting entirely of non-persistent messages.

The rate at which data is written to the log depends on how messages arrive in your system, in addition to the message rate. Non-fast messages received or sent over a channel result in more data logging than messages generated and retrieved locally.

- The rate at which data can be read from the archive and active logs.
 - When reading the logs, the achievable data rate depends on the devices used and the overall load on your particular DASD subsystem. For example, data rates of over 100 MB per second have been observed using active and archive logs on DS8800 DASD.
 - With most tape units, it is possible to achieve higher data rates for archived logs with a large block size.

NOTE: The rates achieved with the DS8800 DASD were on a system with sufficient CPU and capacity to the disks. When the job running the back-up of the page sets had insufficient CPU, the rate that the IDCAMS REPRO job was able to back up dropped from 43MB per second to 8.5MB per second.

Why WebSphere MQ for z/OS changed how it manages small messages in V7.0.1

In version 7.0.1 of WebSphere MQ for z/OS, a change to the way that MQ handles small messages was implemented.

Version 6.0.0 would attempt to fit as many messages as possible into each 4KB page, which gave an increased capacity - for example it was possible to fit 10 messages of 32 bytes onto a single page, which coupled with a 64GB page set limit, meant that a single page set could hold 160 million messages.

There was a downside to this - because more than 1 message could be stored on a single page, it was difficult to know exactly when all of the messages on any particular page had been retrieved and the page became available for new messages. To resolve this problem, a scavenger task would be initiated every 5 seconds to scan all of the pages to identify which pages could be re-used.

As clock speeds have increased, the achievable transaction rate has also increased and allowing a 5 second period between scavenger tasks meant more pages become empty but not marked as available. It also means that the scavenger task has to do more work scanning the chains to determine if a page can be marked as reusable.

From version 7.0.1, small messages are stored one per page. This mean that a 64GB pageset can never contain more than 16 million messages (i.e. 1/10th of the capacity for 32 byte messages).

The benefit of this approach is that once the message has been gotten, the data page can be deallocated immediately - there is no need to wait up to 5 seconds for the scavenger task.

In a high throughput environment, this means that there is less build up of unscavenged messages - so messages are more likely to be found in buffers rather than being in the pageset.

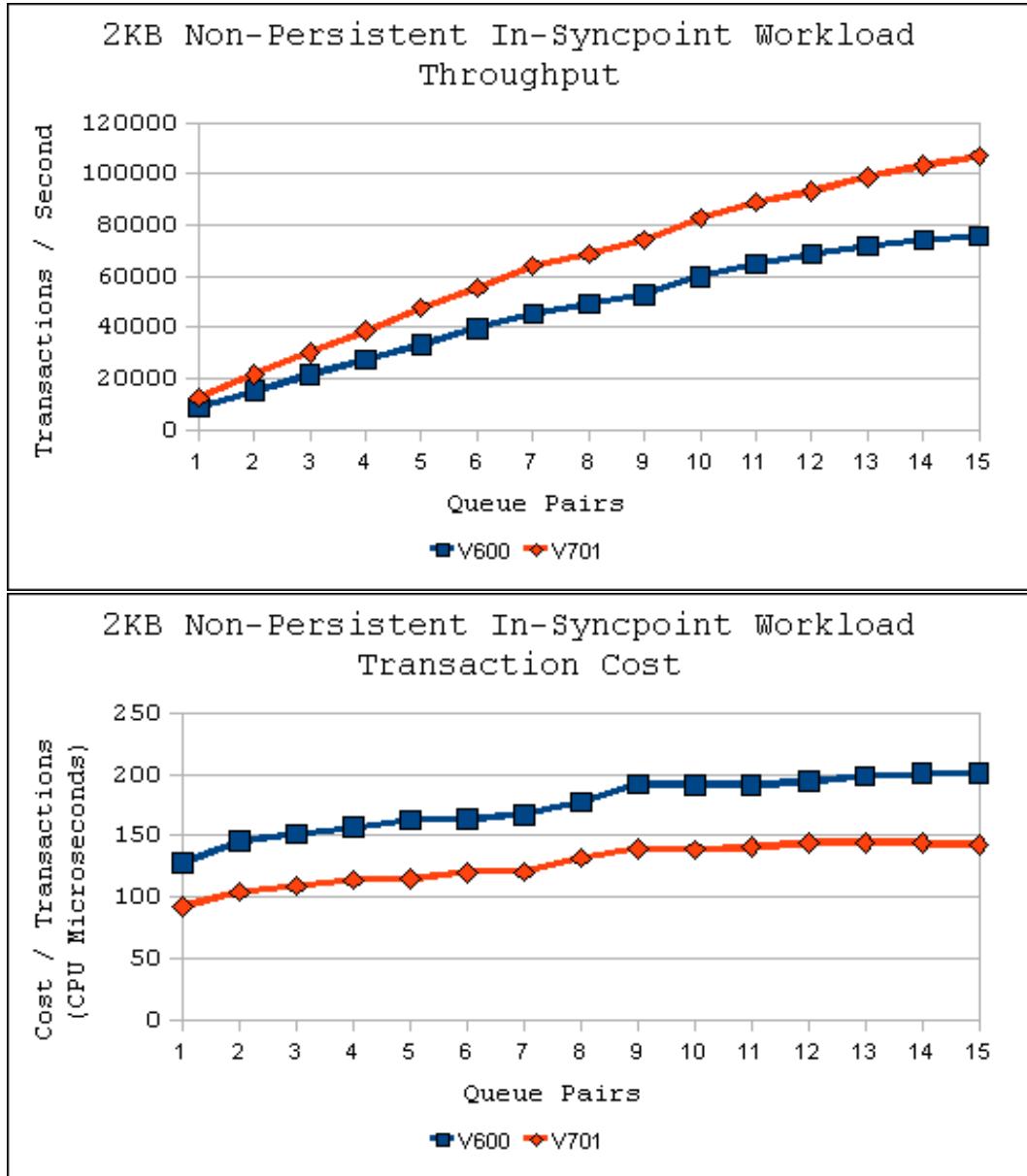
As an example of the benefit of the new approach, this is the output from a “DISPLAY USAGE” command against a V6.0.0 queue manager that has been running a non-persistent workload with 2KB messages where there is never more than 1 message on the queue. In this instance the test has been running for 17 seconds:

Page	Buffer	Total	Unused	Persistent	Nonpersistent	Expansion	
set	pool	pages	pages	data	pages	data	count
-	0	0	20157	19837	320	0	USER 0
-	1	1	268542	102704	29	165809	USER 0
-	2	2	214725	214725	0	0	USER 0

From this message, it can be seen that there are **165,809** pages that are marked as used - this is despite there being only 1 message on the queue at any time.

To further highlight the benefits, 2 charts are included. These show the results of a simple request/reply workload run using 2KB non-persistent private queue messages that are put and gotten in-syncpoint. The measurements start with 1 requester and 1 server performing a request/reply workload with a pair of queues defined on page set 1. As time goes on, more requesters and servers are added - using queues on separate page sets - so there is never more than 1 message on any particular page set.

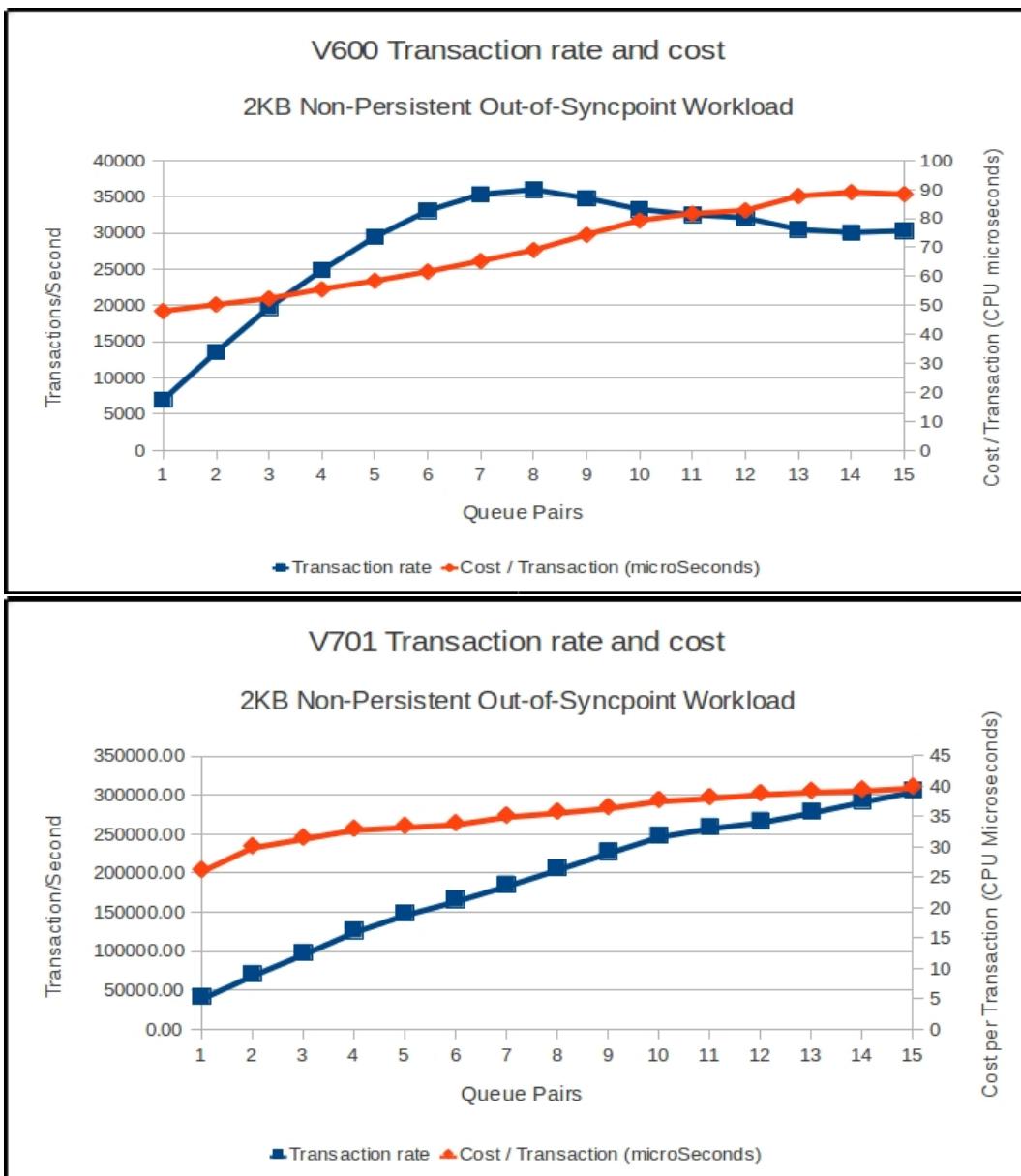
These tests are run on a single z/OS 1.12 LPAR of a zEnterprise 196 (2817) with 16 dedicated processors.



The comparison of non-persistent out-of-syncpoint workloads is even more marked but this is also assisted in the V7.0.1 measurement by the put-to-waiting getter being more likely to be successful. The following 2 charts have been included to compare the results of a simple request/reply workload run using 2KB non-persistent private queue messages that are put and gotten out-of-syncpoint.

The measurements start with 1 requester and 1 server performing a request/reply workload with a pair of queues defined on page set 1. As time goes on, more requesters and servers are added - using queues on separate page sets - so there is never more than 1 message on any particular page set.

These tests are run on a single z/OS 1.12 LPAR of a zEnterprise 196 (2817) with 16 dedicated processors.



NOTE: The y-axis scale is significantly different between the version 6.0.0 and version 7.0.1 charts.

The v6.0.0 measurement peaks at 37,500 transactions per second with a transaction cost between 50 and 80 microseconds. Despite 70% of the messages being put to waiting getter, the 15 pagesets all expanded multiple times - showing that the scavenger was unable to keep up.

The v7.0.1 measurement peaks at 300,000 transactions per second with a transaction cost between 25 and 40 microseconds. There were no pageset expansions nor were there any messages suggesting that the buffer pools were too small.

As the queue manager is not expanding the pagesets to store the unscavenged messages the maximum round-trip for these non-persistent out-of-syncpoint messages drops from 65 milliseconds to 1.1 milliseconds.

Summary

If capacity is the key requirement, then the v7.0.1 small message change may not be the most appropriate as the capacity for small messages can be as little as a tenth of the v6.0.0 capacity.

IBM MQ works more efficiently when queue depths are lower - messages in buffers cost less to get than messages in pagesets, getting messages from deep queues costs more than getting messages from shallow queues - and this small message change continues this theme with significant benefit to throughput.

Buffer pools

A buffer pool is an area of virtual storage in the private region of the queue manager address space. A BUFFPOOL definition gives the size in 4KB pages. Buffer pools are used to minimize I/O to and from page sets on disk. Thus both buffer pool sizes and actual usage can significantly affect the performance of queue manager operation, recovery, and restart. Each message queue is defined to a particular storage class (STGCLASS). Each STGCLASS is assigned to a page set (PSID). Each of the 100 page sets (0 to 99) is assigned to a particular buffer pool (BUFFPOOL). Thus any particular queue uses only one bufferpool and is ultimately stored in only one page set.

An outline of how buffer pools are managed is given in “[Introduction to the buffer manager and data manager](#)”.

Buffer pool default sizes

The following table shows suggested values for buffer pool definitions. Two sets of values are given; one set is suitable for a test system, the other for a production system or a system that will become a production system eventually.

Table: Suggested test and production definitions for buffer pool settings		
Definition setting	Test system	Production system
BUFFPOOL 0	1050 buffers (These were the supplied sample values until release V5.2. They are usually too small for production)	50 000 buffers These are the supplied sample values from release V5.2
BUFFPOOL 1	1050 buffers	20 000 buffers
BUFFPOOL 2	1050 buffers	50 000 buffers
BUFFPOOL 3	1050 buffers	20 000 buffers

Buffer pool usage

From V8.0.0 up to 100 buffer pools (0-99) may be defined, up from the previous limit of 16 buffer pools. This allows a 1:1 mapping of buffer pool to page set so that the buffer pools can be more finely tuned to their usage.

We recommend you use only 4 buffer pool definitions unless you:

1. Have class of service provision reasons for separating one set of queues from another
2. Have known queues which have different behaviour at different times or would otherwise be better isolated in their own individual buffer pools. This might be for their own performance benefit or to protect the performance of the other queues.

Prior to version 8.0.0, the storage for buffer pools was limited to the amount of space available within the overall queue manager address space virtual storage limit. From version 8.0.0, the buffer pools may be allocated using above the bar storage which provides multiple benefits including:

- Larger buffer pools can be allocated which reduce the need for writing to page set and being impacted by the increased I/O time to read/write from page set.
- Makes more space available in the queue manager's 31-bit storage for other things that haven't been moved above the bar e.g. more handles.

NOTE: The optimum value for these parameters is dependent on the characteristics of the individual system. The values given are only intended as a guideline and might not be appropriate for your system. To make good use of the size recommendations you should consider separating buffer pool usage as follows:

- 1. A buffer pool for page set zero and the page set(s) containing system related messages.**

Page set zero contains IBM MQ objects some of which must be frequently updated. For example, queue objects have to maintain a CURDEPTH value. Ideally, keep page set zero for these system-defined objects only. A crude estimate for the number of buffer pool pages required for the system objects in page set zero is half the number of objects.

The page set containing just system related messages, for example page set one, should also map to this buffer pool. System related messages are typically those in the SYSTEM.CLUSTER.* and SYSTEM.CHANNEL.SYNCQ queues

It may be beneficial to put the SYSTEM.CLUSTER.* queues in their own buffer pool.

Queues that can grow large unexpectedly (for example, the dead-letter queue) are particularly inappropriate for this buffer pool. We suggest you put such queues in the ‘everything else’ buffer pool.

This buffer pool should be large enough never to cross the less than 15% free threshold.

This will avoid unnecessary reads from the page set which will effect overall IBM MQ system performance if they are for system objects. A good starting point for the size of this buffer pool might be 50,000 pages.

Alter model queue definitions to point to a storage class other than SYSTEM so that they will not map to buffer pool zero.

- 2. A buffer pool for queues for your important long-lived messages.**

When using buffers from 31-bit storage (below the 2GB bar), a good starting point for the size of this buffer pool might be 20,000 pages.

Long-lived messages are those that remain in the system for longer than two checkpoints, at which time they are written out to the page set.

While it is desirable within limits to define such a buffer pool so that it is sufficiently large to hold all of these messages, it is not advised to exceed 50,000 pages prior to version 8, otherwise there may be a concentration of the necessary page set I/O at checkpoints which might adversely affect response times throughout the system.

Version 8.0 is capable of running with larger buffer pools but be aware of the impact at checkpoint by reviewing the “[Deferred Write Processor](#)” section.

- 3. A buffer pool for queues for your performance critical short lived messages.**

A good starting point for the size of this buffer pool might be 50,000 pages.

This means that you have to have only short lived messages in queues on page sets that you define to this buffer pool. Normally, the number of pages in use will be quite small, however, this buffer pool should be made large to allow for any unexpected build up of messages, such as when a channel or server application stops running.

In all cases, this buffer pool should be large enough never to cross the less than 15% free threshold.

- 4. A buffer pool for everything else.**

You might not be able to avoid this buffer pool crossing the less than 15% free threshold. This is the buffer pool that you can limit the size of if required to enable the other three to be large enough. Queues such as the dead-letter queue, SYSTEM.COMMAND.* queues and SYSTEM.ADMIN.* queues should be placed here. A good starting point for the size of this buffer pool might be 20,000 pages.

See “[Definition of Buffer Pool Statistics](#)” for information about statistics to help monitor buffer pool usage. In particular, ensure that the lowest % free space (QPSTCBSL divided by QPSTNBUF)

is never less than 15% for as many of the buffer pool usage types shown above as possible. Also ensure where possible that the buffer pools are large enough so that QPSTSOS, QPSTSTLA and QPSTDPMC remain at zero.

NOTE: It is good practise to monitor buffer pool usage over a period of time to determine whether particular buffer pools of the appropriate size. If a monitored buffer pool never exceeds 50% used, it may be beneficial to reduce the size which would allow the administrator to allocate this storage to a buffer pool that is too small.

Using buffers allocated in 64-bit storage

Buffer pools can be defined with the attribute LOCATION(ABOVE) so that the buffers are allocated in 64 bit storage. This means that these buffer pools can be made much larger so that all message access is from storage, which can enhance application performance by reducing disk I/O to and from page set.

Page fixed buffers

Even with large buffer pools, for some kinds of processing where queue depths build up where it may not be possible to keep all of the data in the buffer pool. In these cases data is written to the page set during MQPUT and read from page set during MQGET processing. Where the highest levels of performance are required for this type of high I/O intensity workload, the buffer pool can be defined with PAGECLAS(FIXED4KB) which ensures that the buffers are permanently fixed in real storage so the overhead of the page-fix before the I/O and the unfix after I/O is removed.

Why not page fix by default?

If PAGECLAS(FIXED4KB) is specified and there is insufficient real memory available in the LPAR, the queue manager may fail to start or may impact other address spaces.

The effect of buffer pool size on restart time

Restart time is not normally dependent on buffer pool size. However, if there are persistent messages on the log that were not written to a page set before a queue manager failure, these messages are restored from the log during restart and are written to the page set at the checkpoint that occurs following restart completion. This should have no greater impact than any other checkpoint, and might complete before much application activity resumes.

If you reduce the buffer pool size significantly before restarting a system after an abnormal termination, this can lead to a one-time increase in restart time. This happens if the buffer pool is not large enough to accommodate the messages on the log thus requiring additional page set I/O during restart.

For further information on buffer pools, statistics and data manager, see section “[Tuning buffer pools](#)”.

Deferred Write Process

The deferred write process, also known as DWP or DWT, is a set of queue manager tasks that causes data held in buffer pools to be written to page set independently of the putting application(s).

Typically when a buffer pool reaches 85% full, DWP will start to write the oldest data from the buffer pool into the associated page set, making more buffer pool pages available to applications. This will continue until the buffer pool usage drops below 75% full.

Should the rate of data being put onto the buffer pool exceed the rate that DWP can write to page set and the buffer pool usage reaches or exceeds 95% full, then synchronous writes to page set occur, which can increase the elapsed time that an application takes to put a message.

What changed in IBM MQ version 8.0.0?

There were 2 changes in version 8.0 that affected the performance of the DWP.

- Increase in number of buffer pools from 16 to 100.
- Moving buffer pools from 31-bit storage to 64-bit storage. By moving the buffer pools above the 2GB “bar”, the total amount of storage allocated to buffer pools can be much larger than 1GB.

Prior to version 8.0, DWP would write up to 4 pages of data in a single I/O request. With the potential increase in the number of buffer pool pages that may need to be written, this version of DWP could take a substantial time to write the data to page set, and this increased the likelihood that applications putting messages would be affected by synchronous I/Os.

From version 8.0, DWP attempts to write 16 pages of data per I/O request and may have up to 64 parallel I/Os in-flight. This means that DWP can process up to 1024 pages (4MB) of data at a single time per buffer pool. With a maximum of 64 parallel I/Os per buffer pool, the use of HyperPAVs is recommended to exploit these parallel I/Os.

How many DWP tasks are there?

There is a deferred write process for each buffer pool. With version 8.0’s change to support 100 buffer pools, this can have an effect on the number of tasks running within the queue manager.

The DWP is also used during checkpoint processing to process data that has been held in the buffer pool through 2 checkpoints. Once data in buffer pools has been through 2 checkpoints, the DWP task will write the messages to the page set.

How much data could DWP write at checkpoint?

Prior to version 8.0, the total amount of space used by buffer pools was likely to be less than 1GB of the queue managers 31-bit storage.

Since DWP will run when the buffer pool usage reaches 85%, the maximum amount of data that could be written at checkpoint was approximately 85% of 1GB, or around 220,000 pages.

In version 8.0, buffer pools may be much larger although there is no practical benefit in exceeding the size of the page set, which are limited to 64GB. In version 8.0 the maximum amount of data that can be written at checkpoint is actually limited by the log size, which has a maximum size of 4GB.

Note: Determining how much data is written by DWP at checkpoint is not as simple as the size of the log. As discussed in “[How much log space does my message use?](#)”, a 0-byte message put to a local queue will **log** 1057 bytes. However this is not necessarily the same as the amount of data that DWP will write to the page set. DWP will write full 4KB pages - regardless of the data size.

This means that a persistent message of up to 3635 bytes on the buffer pool will result in a 4KB write I/O to the page set.

For a 0 byte message, which caused 1057 bytes to be logged, there could be 3 messages logged per 4KB page, so a 4GB log could contain 12GB of buffer pool data that is eligible to be written by DWP at the second checkpoint.

Where there are multiple messages per commit, the amount of data logged is reduced. For example we have seen 10 messages of 0 bytes in a unit of work caused 751 bytes per message to be logged. In this instance, the log could write 5 messages per 4KB of log space. This has the potential to result in up to 20GB of buffer pool data that is eligible to be written by DWP at the second checkpoint.

What impact is there when DWP writes large amounts of data?

On our systems using DS8870 DASD, the DWP task was able to write data buffer pool to page set at a rate of between 300-600 MB/sec. When there is 4GB of data to be written to a single page set, this can mean that DWP is driving I/O for between 7 to 13 seconds. This increased load on the I/O subsystem can result in an impact on application workload until the DWP workload is complete.

In a system with less responsive DASD, the impact may be greater. For example if DWP is only able to write the 4GB of data at 100MB per second, there could be 41 seconds where an application workload using **persistent** messages is affected by the moving of data from buffer pool to page set.

The use of higher performance FICON (zHPF) can reduce the impact on active workload when the queue manager DWP is initiated to write large amounts of data from buffer pool to page set.

DWP is also used at queue manager shutdown to write any persistent messages from buffer pool to page set but as there is less likely be MQ workload running on the queue manager, it is unlikely to be impacted.

Recovery

Achieving specific recovery targets

If you have specific recovery targets to achieve, for example, completion of the queue manager recovery and restart processing in addition to the normal startup time within xx seconds, you can use the following calculation to estimate your backup frequency (in hours):

Formula (A)

Backup frequency = $\frac{(\text{Required restart time} * \text{System recovery log read rate})}{\text{Application log write rate}}$

For example, consider a system in which IBM MQ clients generate an overall load of 100 persistent messages per second. In this case, all messages are generated locally. If each message is of user length 1 KB, the amount of data logged per hour is of the order:

$100 * (1 + 1.3 \text{ KB}) * 3600 \text{ seconds} = \text{approximately } 800 \text{ MB}$
where

100 = message rate per second

$(1 + 1.3 \text{ KB})$ = amount of data logged for each 1KB persistent message.

Consider an overall target recovery time of 75 minutes. If you have allowed 15 minutes to react to the problem and restore the page set backup copy, queue manager recovery and restart must then complete within 60 minutes applying formula (A). This necessitates a page set backup frequency of at least every:

$$3600 \text{ seconds} * 36 \text{ MB per second} / 800 \text{ MB per hour} = 162 \text{ hours}$$

This backup time means that there would be 126GB of data to restore – but it would be better to recover the data from the active logs.

For example if the active logs are 2GB each and there are 10 logs, there are only 20GB of data available on the active logs. Based on this the backup would need to occur every 25 hours

$$20 \text{ GB} / 800\text{MB per hour} = 25.6 \text{ hours}$$

This assumes that all required log data is on DS8000 DASD. (If you can only read from the log at 0.5MB per seconds the calculation would be every:

$$3600 \text{ seconds} * 0.5 \text{ MB per second} / 800 \text{ MB per hour} = 2.25 \text{ hours}$$

If your IBM MQ application day lasts approximately 12 hours, one backup every 2 days is appropriate. However, if the application day lasts 24 hours, one backup every day is more appropriate.

Another example might be a production system in which all the messages are for request-reply applications (that is, a persistent message is received on a receiver channel and a persistent reply message is generated and sent down a sender channel).

In this example, the achieved batch size is one, and so there is one batch for every message. If there are 50 request replies per second, the overall load is 100 persistent messages per second. If each message is 1 KB in length, the amount of data logged per hour is of the order:

$50((2 * (1+1.3 \text{ KB})) + 1.4 \text{ KB} + 2.5 \text{ KB}) * 3600 = \text{approximately } 1500 \text{ MB}$

where:

50	= message pair rate per second
(2 * (1 + 1.3 KB))	= amount of data logged for each message pair
1.4 KB	= overhead for each batch of messages received by each channel
2.5 KB	= overhead for each batch of messages sent by each channel

In order to achieve the queue manager recovery and restart within 30 minutes (1800 seconds) requires that page set backup is carried out at least every:

$$1800 \text{ seconds} * 2.7 \text{ MB per second} / 1500 \text{ MB per hour} = 3.24 \text{ hours}$$

This assumes that all required log data is on similar DASD.

Periodic review of backup frequency

You are recommended to monitor your IBM MQ log usage in terms of MB per hour (log size in MB over hours to fill that log).

You should perform this check periodically and amend your page set backup frequency if necessary.

Restart

How long will my system take to restart after a failure?

This section describes the factors relating to recovery that affect the restart time of a queue manager:

- What happens when a transaction processes an IBM MQ request. This describes the stages that a transaction goes through.
- What happens during the recovery phase of restart.
- How long each recovery phase of restart takes.
- An example of a calculation of time required for the recovery phase of restart.

The length of time that a queue manager takes to restart depends on the amount of recovery that it has to do. This covers recovery of applications that were processing persistent messages (transactional recovery), and media recovery which involves both recovery of a page set after a failure and recovery of persistent messages in a buffer pool that had not been written to a page set.

There are four stages to the recovery phase of the log during restart

1. Preparing for recovery.
2. Determining the status of IBM MQ and connected tasks at the point of failure. This includes identifying the lowest page set recovery RBA.
3. Bringing the system up to date: this might involve media recovery and forward transaction recovery of in-doubt and in-commit transactions.
4. Backing out changes for those tasks that were in-flight and in-backout at the time the queue manager stopped.

Other factors that may affect restart times include:

- Rebuilding indexed queues - refer to performance report "[MP1G](#)" section on "Indexed queues".

- Rebuild subscriptions - refer to performance report “[MP1F](#)” section on "Subscriptions".
- Structure recovery - refer to performance report “[MP1H](#)” section on "Recovery".

To understand what happens in these log recovery stages you need to understand what happens to a transaction as it updates recoverable resources (such as persistent messages) and commits them. You also need to understand what happens at when a checkpoint occurs. The next section gives a simplified description of these things.

What happens as a transaction processes an IBM MQ request Consider a CICS transaction that gets two persistent IBM MQ messages, updates a DB2 table, and commits the work by issuing the EXEC CICS SYNCPOINT command. This will use two-phase commit because resources in both IBM MQ and DB2 are updated.

Transaction activity	What happens within the queue manager
Transaction starts.	Internal IM MQ state: Initial state
MQGET request issued.	<p>The message is locked.</p> <p>Because a unit of recovery did not exist for this transaction:</p> <ul style="list-style-type: none"> • A unit of recovery is created. • The state is changed to "in flight". • A "Start unit of recovery" (Start UR) is moved to the log buffers. • The LOG RBA of this record is saved as STARTRBA in the unit of recovery record. <p>The "message deleted" flag is set in the message, and this change is moved to the log buffers.</p> <p>The current queue depth is decremented and this change is also moved to the log buffers.</p> <p>Final internal IBM MQ state: In flight.</p>
MQGET the second message.	<p>The message is locked.</p> <p>The "message deleted" flag is set in the message, and this change is moved to the log buffers. The current queue depth is decremented and this change is also moved to the log buffers.</p> <p>Final internal IBM MQ state: In flight.</p>
DB2 table update made	
EXEC CICS SYNC-POINT issued.	
CICS issues the first part of the two phase commit (the prepare request) to IBM MQ.	<p>A "Begin Commit phase 1" is moved to the log buffers.</p> <p>The state is changed to "In commit 1".</p> <p>Resource managers prepare for the commit.</p> <p>The state is changed to "In doubt".</p> <p>An "End commit phase 1" record is moved to the log buffers and the RBA of this record is saved in the ENDRBA field of the unit of recovery record</p> <p>The log buffers up to and including this record are forced to disk.</p> <p>Returns "OK" to CICS.</p> <p>Final internal IBM MQ state: In doubt.</p>
CICS issues the prepare to DB2.	See Note.
Providing both IBM MQ and DB2 replied OK, CICS issues the second part of the two phase commit (the commit) to MQSeries.	<p>A "Phase 1 commit to Phase 2 commit" record is moved to the log buffers.</p> <p>The state is changed to "In commit 2", the transaction is now in "Must complete" state.</p> <p>The log buffers up to and including this record are forced to disk.</p> <p>The state is set to "End phase 2 commit".</p> <p>An "End phase 2 Commit" record is moved to the log buffers.</p> <p>Any locked resources are unlocked.</p> <p>The unit of recovery is deleted.</p> <p>The state is set to "Initial state". Returns to CICS.</p> <p>Final internal MQSeries state: Initial state</p>

<p>Providing both MQSeries and DB2 replied OK, CICS issues the second part of the two phase commit (the commit) to DB2.</p>	<p>NOTE: The calls to DB2 describe what logically happens. In practice, CICS optimizes the call to the last resource manager by passing the prepare and commit request together. In this example, DB2 was the last resource manager, in other cases IBM MQ might be the last resource manager, and so the prepare and commit requests would be treated as one request.</p>
<p>Note: If any resource manager is unable to commit, the requests are backed out</p>	

What happens during a checkpoint

During a checkpoint, information about the following items is moved to the log buffers and the buffers are forced to DASD.

- Incomplete units of recovery.
- Recovery RBAs of all page sets.
- Unit of work descriptors for peer recovery.
- IMS bridge checkpoint and all Set and Test Sequence Number (STSN) information.

When a checkpoint occurs it starts a process for writing old changed buffer pool pages to disk. These disk writes are not part of the checkpoint itself.

What happens during the recovery phase of restart

The following figure shows an example of the messages produced during the recovery phase of restart: The messages are described in the following text.

Figure: Example queue manager job log showing recovery messages

```
CSQJ099I @12A LOG RECORDING TO COMMENCE WITH
STARTRBA=0211B7845000
CSQR001I @12A RESTART INITIATED
CSQR003I @12A RESTART...PRIOR CHECKPOINT RBA=0211B7842C44
CSQR004I @12A RESTART...UR STATUS COUNTS
IN COMMIT=1, INDOUBT=0, INFLIGHT=1, IN BACKOUT=0
CSQR007I @12A STATUS TABLE
T CON-ID THREAD-XREF S URID DAY TIME
-----
S IYCPVC01 1119E2ACC3D7F1F50000032C C 0211B7843536 138 16:59:32
S IYCPVC01 1119E2ACC3D7F1F50000036C F 0211B7F88502 138 17:05:51
CSQR005I @12A RESTART...COUNTS AFTER FORWARD RECOVERY IN COMMIT=0,
INDOUBT=0
CSQR006I @12A RESTART...COUNTS AFTER BACKWARD RECOVERY INFLIGHT=0, IN
BACKOUT=0
CSQR002I @12A RESTART COMPLETED
```

Phase 1, restart begins

The queue manager displays message CSQR001I to indicate that restart has started.

```
CSQR001I @12A RESTART INITIATED
```

The CSQJ099I message preceding the CSQR001I message contains the approximate RBA at the point of failure.

```
CSQJ099I @12A LOG RECORDING TO COMMENCE WITH STARTRBA=0211B791A000
```

Phase 2, determine the state of the system at point of failure

1. The last checkpoint record is located from the BSDS.
[CSQR003I @12A RESTART...PRIOR CHECKPOINT RBA=0211B7842C44](#)
2. The recovery RBAs of each page set are read from the checkpoint records.
3. Page 0 of every page set is read to obtain the last logged RBA for the page set. The lowest RBA of all the page sets is used to determine where the log should be read from for media recovery.
4. An in-memory table is built from information in the checkpoint records of the tasks that were active at the checkpoint.
5. The log is read in a forward direction from the checkpoint to the point of failure. The in-memory table is updated as tasks complete or new tasks start.
6. Message CSQR004I displays how many tasks were in each state at the point of failure.

```
CSQR004I @12A RESTART...UR STATUS COUNTS IN COMMIT=1, INDOUBT=0,
INFLIGHT=1, IN BACKOUT=0
```

Phase 3, forward recovery

1. A list of all of the log ranges required for forward recovery is built from the list of tasks that are in doubt and in commit. **Note:** Because the log ranges between the STARTRBAs and

ENDRBAs are known from the units of recovery, only the logs that contain these ranges are used. This means that some archives might not be used.

2. The range of log records for the page sets is from the earliest RBA in the page sets up to the point of failure. In normal operation the earliest RBA is within three checkpoints before the point of failure. If it has been necessary to use a backup version of a page set, the earliest RBA might be considerably earlier.
3. These ranges are combined, and a list is built of the required log ranges and the corresponding active or archive logs. The logs are read from the lowest RBA to the highest.
Note: The logs are searched sequentially from the beginning of the data set until the start of the required log RBA is found, and then read to the end RBA.
4. For each task that is in commit, log records between the start of the unit of recovery and the ENDRBA are processed, and the changes reapplied.
5. For each task that is in doubt, log records between the start of the unit of recovery and the ENDRBA are processed, and the changes reapplied. Locks are obtained on resources as required in the same way that they are obtained during normal operation.
6. The log is read from the lowest RBA for all of the page sets and the data is replayed to rebuild the buffer pools (and the page sets if you are recovering from a backup version) as they were at the point of failure. All log records from the earliest required RBA are read, even if they do not apply to the particular page set.
7. These forward recovery steps are combined in one forward scan of the log.
8. Once this forward recovery has completed, transactions in "must-commit" state are completed. All in-doubt units of recovery stay in doubt (with any resources still locked) until they are resolved, (for example when the CICS region reconnects).
9. Message CSQR005I displays how many tasks are in commit or in doubt after forward recovery.

```
CSQR005I @12A RESTART...COUNTS AFTER FORWARD RECOVERY IN COMMIT=0,  
INDOUBT=0
```

Phase 4, backward recovery.

1. The log records for in-flight or in-backout transactions are processed and any changes made by these transactions are undone.
2. Every log record is processed from the last written record, back to the earliest RBA of any transaction that was in flight or in backout. You can determine this RBA from the URID specified in message CSQR007I for records with a status of F or A.

CSQR007I @12A STATUS TABLE					
T	CON-ID	THREAD-XREF	S	URID	DAY TIME
-	-	-	-	-	-
S	IYCPVC01	1119E2ACC3D7F1F50000032C	C	0211B7843536	138 16:59:32
S	IYCPVC01	1119E2ACC3D7F1F50000036C	F	0211B7F88502	138 17:05:51

3. Message CSQR002I is issued at completion.

```
CSQR006I @12A RESTART...COUNTS AFTER BACKWARD RECOVERY INFLIGHT=0, IN  
BACKOUT=0  
CSQR002I @12A RESTART COMPLETED
```

How long will each phase of the recovery take?

Most of the time taken to recover is spent processing the active or archive logs. This has two components:

1. Making the data sets available to the queue manager (for example mounting a tape or recalling a data set from HSM for archive logs).

This time depends on your operational environment and can vary significantly from customer to customer.

2. Reading the active and archive logs.

This depends on the hardware used, for example DASD or tape, and the speed at which data can be transferred to the processor. (On DS8800 DASD we achieved between 56 MB per second reading the logs backwards and 105 MB per second reading the logs forwards.)

The figures below estimate the time needed to read the logs for each stage of recovery. You should include your estimate of how long it will take to make the media available.

Phase 1, restart begins The recovery environment is established, so this is very short.

Phase 2, determine the state of the system at the point of failure The active log that was being used at the point of failure is read from the start to locate the last checkpoint (this might be at the start of the log). The log is then read from this checkpoint up to the point of failure.

The point of failure could be just before another checkpoint was about to be taken, in the worst case, the point of failure might be at the end of a log. You can estimate how much data is written between checkpoints by calculating the size of a log divided by the number of checkpoints in the time it takes to fill this log. (In our tests, with a log of 1000 cylinders of 3390 it took approximately 5 minutes to read to the end of this log.)

When reading the log data sets, the I/Os are performed such that multiple pages are read in parallel and will benefit from z/OS features such as HyperPav being available.

The size of the messages being processed can impact the CPU time taken in this phase of recovery, as a workload consisting of small messages may result in a higher usage of CPU time (SRB) than the equivalent amount of data being recovered from a large message workload, which in a CPU constrained system may increase the elapsed time for restart. For example, when restarting a queue manager with LOGLOAD of 4,000,000 that had been processing 2KB messages and the recovery range was 2GB, the elapsed time and CPU cost was 22 seconds on a 2964-703 that was not constrained for CPU.

Phase 3, forward recovery This covers three activities:

- Recovering in-commit and in-doubt tasks.
- Applying changes to a page set if a backup copy has been used.
- Rebuilding the page sets to the point of failure.

The duration of forward recovery is primarily dependent upon the number of pages that need to be read from page set as the I/O must be performed serially one page at a time, as well whether all of the changed data can be help in buffer pools.

The CSQR030I message reports the range of data that may be processed as part of forward log recovery. From this range, the maximum number of pages that may need to be read from disk can be calculated by dividing the difference by 4096.

On our test systems connected to DS8870 DASD, each read of a 4KB page took approximately 230 microseconds, which equates to 4300 pages per second (16.8MB/second).

When z High Performance Ficon (zHPF) was enabled, the page I/O time was reduced and gave approximately a 40% improvement in read rate.

The number of pages that need to be read will depend on the workload and in our tests saw instances of between 10% and 100% of the pages specified by the CSQR030I message having to be read from disk.

Phase 3, Recovering in-commit and in-doubt tasks Most time is spent reading the logs between the STARTRBA and ENDRBA for in-doubt and in-commit tasks. The log is read in a forward direction until the start RBA is located, and then the records are read and processed from that point. If a unit of recovery spans more than one tape, the whole of the first tape has to be read. For in-doubt tasks, any locks are re-obtained. Backwards log recovery is dependent upon the number of long running tasks that need to be recovered, but it should be noted that the data is not read backwards, instead the starting record is read directly and then the logs are processed forwards.

Tasks that have been through 2 checkpoints and have been log shunted may require less data to be read for recovery.

In our measurements using simple long running tasks, such as those that put a message and wait prior to committing the data, backwards recovery was of the order of 10 seconds or less but with more tasks to recover, backwards recovery may take longer.

Phase 3, Applying changes to a page set if a backup copy has been used If a backup copy of a page set is used, the log needs to be read from the point when the backup was taken, and all records read forward from that point. If you did not record the log RBA when the backup was taken, you can use the date and time when the backup was taken and look in a printout of the BSDS to find the archive logs that will be needed.

To calculate the time needed to read the logs:

1. Calculate the difference between the log RBA at the start of backup and the RBA at the point of failure (the STARTRBA value in message CSQJ099I).
If the backup was taken when the queue manager was active (a fuzzy backup), the RBA in the page set might be up to three checkpoints before the RBA when the backup was taken. This might be up to three additional archive logs.
2. Divide the RBA range (in MB) by the data rate your DASD or TAPE can sustain to calculate the time required to process this amount of data.

The worst case is when there is a damaged page set that was not backed up and has to be redefined. This sets the page set RBA to 0, and so all logs from the very first are required for recovery. In the example above, the previous checkpoint is 0211B7842C44. This is about 2 300 GB of data. If this can be read at 56 MB per second, this will take almost 12 hours.

If the page set had been backed up when the queue manager was down at the RBA of 021000000000, the required range of RBAs is 0211B7842C44 - 021000000000 (about 7000 MB of data). If this can be read at 56 MB per second, this is about 2 minutes plus the time to read from the checkpoint to the point of failure. You also need to add the time taken to make any archive log available, and include the time to restore the page set from a backup copy.

It is significantly faster to use DFDSS dump and restore than to use IDCAMS REPRO. For example, for a dataset of 1600 cylinders DFDSS dump took 15 seconds, and IDCAMS REPRO took 26 seconds. In both cases the backup dataset was the same size as the original dataset.

Rebuilding the page sets to the point of failure To recover a page set, up to three checkpoints worth of data has to be read from log. This is typically two checkpoints worth, but if the system failed when processing a checkpoint, three checkpoints worth of data needs to be processed. By having at least three active log data sets, you will ensure that these records are read from the active logs, and not archive logs.

Phase 4, undo any changes for tasks that were in flight or in backout (backward recovery) The log has to be read in a backward direction from the point of failure to the earliest URID for those tasks that were in flight or in backout (a status of F or A). Reading backwards is considerably slower than reading forwards, (by a factor of 5 on some tapes, and on our DS8800 was half the rate of reading forwards), and is even slower if data compaction is used. In the example above, if the system failed when the RBA was 211F0000000, there is about 900 MB of data to be read. If the rate of reading backwards is 56 MB per second this will take about 16 seconds.

Example of calculation of restart time This section gives a worked example for the time taken to restart a queue manager that had tasks in different states when it stopped.

The calculations are to give an indication of the time taken to recover, for example, will a queue manager take 10 minutes or 10 hours to restart, rather than an accurate value.

Configuration

Dual logging was used, with 3 active logs in a ring. Each log was 100 cylinders of 3390 (about 74 MB each). Small logs were used for illustration purposes.

When archiving to tape, a Virtual Tape System (3494-VTS B16) was used. This looks like a 3490E to z/OS. Physically, the data is written to DASD before being ultimately staged to a 3590 tape.

Request/reply CICS transactions were used. The transaction put a 1000-byte persistent message to a server queue, and a batch server retrieved the message and put the reply back to the originator.

The in-doubt, in-flight, and in-commit transactions were achieved as follows:

- CEDF was used to suspend the in-flight transaction after the transaction had written a message and before the commit. Many transactions were run.
- The in-doubt transaction was created by suspending the application before the "Phase 1 commit to Phase 2 commit" was moved to the log buffers. Many transactions were run.
- The in-commit transaction was suspended the same way as the in-flight transaction. Many transactions were then run and the in-commit transaction was allowed to commit. The queue manager was then cancelled. Because the "End phase 2 commit" had not been written to the log data set, the transaction becomes in commit at system restart. If any other transaction had run that caused the log buffers to be forced to disk, the in-commit transaction would have had its "End phase 2 commit" written to the log data set, and would be seen as having completed at system restart.

The following table shows the tapes that were used, and their RBA ranges:

Number	STARTRBA	ENDRBA
1	0	000000009FFF
2	00000000A000	000004659FFF
3	00000465A000	000008CA9FFF
4	000008CAA000	00000D2F9FFF
5	00000D2FA000	000011949FFF
6	00001194A000	000015F99FFF
7	000015F9A000	00001A5E9FFF
8	00001A5EA000	00001EC39FFF
9	00001EC3A000	000023289FFF
10	00002328A000	0000278D9FFF

The log data on tapes 9 and 10 is still available on the oldest two of the ring of active logs. Active logs are always used in preference to archive logs where possible.

Output from when the queue manager was restarted after it was cancelled Phases 1 and 2, - estimate of the time needed

The following figure shows an example of output from a queue manager at restart:

08.36.13 CSQJ099I @V21A LOG RECORDING TO COMMENCE WITH
STARTRBA=0000296A8000
08.36.13 CSQR001I @V21A RESTART INITIATED
CSQR003I @V21A RESTART...PRIOR CHECKPOINT RBA=0000278DF333
08.36.27 CSQR004I @V21A RESTART...UR STATUS COUNTS
IN COMMIT=1, INDOUBT=1, INFLIGHT=1, IN BACKOUT=0
CSQR007I @V21A STATUS TABLE
T CON-ID THREAD-XREF S URID TIME
- - -
S IYCPVC02 1869E2ACC3D7F2F50000046C F0000000A1F55 .. 08:14:35
S IYCPVC02 1869EE04C9D5C3D40016274C D0000046280C4 .. 08:18:56
S IYCPVC02 1869F206C3D7F2F50034023C C000008E340AO .. 08:24:11

This shows that the time between issuing message CSQR001I and message CSQR004I (phase 1) is 14 seconds.

- The RBA in the CSQJ099I message (0000296A8000) is just after the point of failure.
- The last checkpoint is at 0000278DF333.
- The number of bytes between these two values is approximately 31 MB.
- If the log can be read at 2.7 MB per second, this will take about 12 seconds.

Phase 3, forward recovery - estimate of the time needed

- Tape 2 was read forwards and took 21 seconds. This is for the in-doubt transaction.
- Tapes 4 through 8 were read forwards; each tape took about 25 seconds to read. Tapes 9 and 10 were not needed because the data was still in active logs. This is for the in-commit transaction.

08.47.05 CSQR005I @V21A RESTART...COUNTS AFTER FORWARD RECOVERY
IN COMMIT=0, INDOUBT=1
CSQR007I @V21A STATUS TABLE
T CON-ID THREAD-XREF S URID TIME
- - -
S IYCPVC02 1869EE04C9D5C3D40016274C D0000046280C4 .. 08:18:56

The time taken between issuing message CSQR005I and message CSQR004I was 10 minutes 38 seconds, of which 6 minutes 30 seconds was spent mounting the tapes. The tapes were being read for just over 4 minutes. There is one task in commit and one in doubt.

The in-commit and in-doubt tasks are processed during forward recovery and the in-flight task is processed during backward recovery. There is no way of knowing when the last RBA was written for the in-doubt or in-commit units of recovery. For normal, well-behaved, transactions the time between the start of the unit of recovery and the commit request is short, but it might take a long time for the in-doubt unit of recovery to be resolved.

Processing the in-doubt transaction The in-doubt transaction was created by suspending the application before the "Phase 1 commit to phase 2 commit" was written to the logs. This was the only transaction running at the time so the RBA range between the STARTRBA and the point where the transaction was suspended was small.

The log has to be read from the "Start UR" to the "End commit phase 1". The STARTRBA is on tape 2 and the log has to be read sequentially to locate the STARTRBA. Then the log is read and processed up to the ENDRBA.

The START UR of the in-doubt transaction is 0000046280C4 and the STARTRBA of tape 2 is 00000000A000. The number of bytes to be read to locate the STARTRBA is:

0000046280C4 - 00000000A000 = 74MB

The test system can achieve a rate of 2.7 MB per second which means that it takes 27 seconds to read 74MB. The time taken to read the records for the unit of recovery up to the ENDRBA is small in this example. (In the example above, Tape 2 was read for 27 seconds.)

Processing the in-commit transaction The in-commit transaction put a message and was suspended the same way as the in-flight transaction. Many other transactions then ran. This suspended transaction was then allowed to commit, in the sense that the "end phase 2 commit" was moved to the log buffers. Before the buffers were written to the log data set the queue manager was cancelled. Because the "End phase 2 commit" has not been moved to the log data set, it becomes in commit at system restart.

- The STARTRBA of the transaction is on tape 4, and the whole of the tape has to be read, from RBA 000008CAA000 forward. It is read from the start of the tape up to the STARTRBA, and then from the STARTRBA up to the commit records.
- You might know how your applications behave, and know if they have long units of recovery. In this example the ENDRBA is at the point of failure (0000296A8000).
- The amount of data to be read is 0000296A8000 - 000008CAA000. This is about 547 MB. On the test system, this could be read in 202seconds (at a rate of 2.7MB per second).In the above example, this was read in about 240 seconds.

Recovery of the buffer pools The RBA from the page sets is within three checkpoints of the point of failure. The checkpoints were occurring when the log switched, so up to three active logs have to be read. Each log is 74MB, and at 2.7 MB per second will take about 27 seconds per log. For three checkpoints this will be 82 seconds. This activity occurs in parallel to the recovery of the in-commit and in-doubt tasks.

Total time for this forward recovery The time taken for forward recovery is the greater of:

- 27 seconds for the in-doubt unit of recovery plus 202 seconds for the in-commit unit of recovery
- 82 seconds for the recovery of the buffer pools which is approaching 4 minutes, and close to the actual elapsed time.

Phase 4, backward recovery - estimate of time needed The active logs were read backwards, so the archive logs on tape 10 and 9 were not needed.

08.47.05 CSQR007I @V21A STATUS TABLE				
T	CON-ID	THREAD-XREF	S	URID

S	IYCPVC02	1869EE04C9D5C3D40016274C	D0000046280C4	...
08.47.54	IKJ56221I	DATA SET MQMDATA.TAPE.V21A1.A0000008	NOT ALLOCATED...	

This shows that it took 54 - 05 = 49 seconds to process the log records already in memory and to read the active logs backwards.

- Tapes 2 through 8 were read backwards taking between 85 and 140 seconds per tape, for a total of 12 minutes 31 seconds.

```
09.04.50 CSQR006I @V21A RESTART...COUNTS AFTER BACKWARD  
RECOVERY  
INFLIGHT=0, IN BACKOUT=0  
CSQR002I @V21A RESTART COMPLETED
```

The time taken between issuing message CSQR006I and message CSQR005I is 17 minutes 45 seconds, of which 4 minutes was spent mounting the tapes and 12-13 minutes reading the tapes.

There is one task in flight with an RBA of 0000000A1F55. The log has to be read backwards from the point of failure to this RBA.

The point of failure is at 0000296A8000, so the amount of data to be read is 0000296A8000 - 0000000A1F55. which is nearly 700 MB. If the rate for reading data backwards is about 0.5 MB per second this will take about 1400 seconds (nearly 24 minutes). ¹

Total restart time The time for recovery is the total of the time in the three phases, that is 11 seconds + 202 seconds + 24 minutes (nearly half an hour) plus the time to mount tapes (for example, 13 tapes at 1 minute each) giving a total time of nearly 45 minutes.

NOTE: These numbers are on older hardware and the logs are deliberately small to highlight the recovery process and time.

¹

Using the Virtual Tape System, where the data had not been destaged to 3590 tapes, the data could be read at about 2.6 MB per second. When the data had been moved to tape, the average rate was about 0.6 MB per second, this includes the time to locate and mount the tape as well as reading it.

Messages which show the page set status at startup

A message CSQI049I is produced to show the RBA needed by each page set during forward recovery. If the two RBA values are different this is due to a page set backup being used.

```
09.37.29 CSQI049I @# Page set 0 has media recovery  
RBA=0000479AF9FA, checkpoint RBA=0000479AF9FA  
09.37.29 CSQI049I @# Page set 1 has media recovery  
RBA=0000479AF9FA, checkpoint RBA=0000479AF9FA  
09.37.29 CSQI049I @# Page set 2 has media recovery  
RBA=0000479AF9FA, checkpoint RBA=0000479AF9FA  
09.37.29 CSQI049I @# Page set 3 has media recovery  
RBA=0000479AF9FA, checkpoint RBA=0000479AF9FA
```

Messages to show progress during forward and backward recovery There are 4 messages:

CSQR030I

This shows the maximum log range required for forward recovery.

Note: Not every log in this range might be needed.

CSQR031I

This message is produced approximately every 2 minutes, and shows the current log RBA being processed during forward recovery. From two of these messages, and the RBA range in message CSQR030I, you should be able to calculate the maximum time the forward recovery phase will take. You will also need to include the time taken to make the archive logs available. Active and archive logs might be on different media and thus be processed at different rates.

CSQR032I

This shows the maximum log range required for backward recovery. Every log in this range will be needed.

CSQR033I

This message is produced approximately every 2 minutes, and shows the current log RBA being processed during backward recovery. From two of these messages, and the RBA range in message CSQR032I, you should be able to calculate the maximum time the forward recovery phase will take. You also need to include the time taken to make the archive logs available.

```
09.37.30 CSQR030I @# Forward recovery log range  
from RBA=0000479AF9FA to RBA=0000479B33A0  
09.37.30 CSQR005I @# RESTART...COUNTS AFTER FORWARD RECOVERY  
IN COMMIT=0, INDOUBT=0  
09.37.30 CSQR032I @# Backward recovery log range  
from RBA=0000479B33A0 to RBA=000008561B58  
09.38.43 CSQR033I @# Reading log backwards, RBA=00003E022000  
09.40.43 CSQR033I @# Reading log backwards, RBA=00002E39A11D  
09.42.43 CSQR033I @# Reading log backwards, RBA=00001E686466  
09.44.43 CSQR033I @# Reading log backwards, RBA=00000EAB6000  
09.45.31 CSQR006I @# RESTART...COUNTS AFTER BACKWARD RECOVERY  
INFLIGHT=0, IN BACKOUT=0  
09.45.31 CSQR002I @# RESTART COMPLETED
```

Messages about page set recovery RBA produced at checkpoints Message CSQP021I is produced during a checkpoint. It identifies the RBA stored in page 0 of the page set, and the lowest RBA of any page in the buffer pool for that page set. These values are usually the same.

```
09.45.31  CSQP018I @# CSQPBCKW CHECKPOINT STARTED FOR ALL BUFFER POOLS
09.45.31  CSQP021I @# Page set 0 new media recovery
RBA=0000479B4000, checkpoint RBA=0000479B4000
09.45.31  CSQP019I @# CSQP1DWP CHECKPOINT COMPLETED FOR BUFFER
POOL 3, 2 PAGES WRITTEN
09.45.31  CSQP021I @# Page set 1 new media recovery
RBA=0000479B4000, checkpoint RBA=0000479B4000
09.45.31  CSQP021I @# Page set 2 new media recovery
RBA=0000479B4850, checkpoint RBA=0000479B4850
09.45.31  CSQP021I @# Page set 3 new media recovery
RBA=0000479B50A0, checkpoint RBA=0000479B50A0
09.45.31  CSQP019I @# CSQP1DWP CHECKPOINT COMPLETED FOR BUFFER
POOL 2, 19 PAGES WRITTEN
09.45.32  CSQP019I @# CSQP1DWP CHECKPOINT COMPLETED FOR BUFFER
POOL 1, 21 PAGES WRITTEN
09.45.32  CSQP019I @# CSQP1DWP CHECKPOINT COMPLETED FOR BUFFER
POOL 0, 87 PAGES WRITTEN
09.45.32  CSQY022I @# QUEUE MANAGER INITIALIZATION COMPLETE
09.45.32  CSQ9022I @# CSQYASCP 'START QMGR' NORMAL COMPLETION
```

What happens during the recovery phase of restart when in a QSG

The following figures show examples of the additional messages produced during recovery phase of restart when the queue manager is in a queue sharing group.

Reconnecting to the structures in the coupling facility

```
12.14.45 CSQE140I @VTS1 CSQEEENFR Started listening for ENF 35
events for structure CSQ_ADMIN
12.14.45 IXL014I IXLCCONN REQUEST FOR STRUCTURE PRF5CSQ_ADMIN
WAS SUCCESSFUL.  JOBNAME: VTS1MSTR ASID: 0C91
CONNECTOR NAME: CSQEPRF5VTS101 CFNAME: AACFO1
ADDITIONAL STATUS INFORMATION:

CONNECTION HAS BEEN REESTABLISHED
12.14.45 CSQE141I @VTS1 CSQEEENFR Stopped listening for ENF 35
events for structure CSQ_ADMIN
12.14.45 CSQE005I @VTS1 CSQECONN Structure CSQ_ADMIN connected
as CSQEPRF5VTS101, version=CA5DC40EEF336E88 0001043C
12.14.45 CSQE021I @VTS1 CSQECONN Structure CSQ_ADMIN
connection as CSQEPRF5VTS101 warning, RC=00000004 reason=02010407
codes=00000000 00000000 00000000
```

The queue manager attempts to reconnect to the named structure when it is notified that the coupling facility is available. The queue manager then connects to the named structure but issues warning with reason 02010407 (IXLRSNCODESPECIALCONN). These messages may be repeated for the application structures too.

CFLEVEL(5)

```
12.14.45 CSQE252I @VTS1 CSQEDSS4 SMDS(VTS1)
CFSTRUCT(APPLICATION1) data set MQMDATA.VTS1.SMDS.APPL1 space map
will be rebuilt by scanning the structure
12.14.45 CSQE255I @VTS1 CSQEDSS4 SMDS(VTS1)
CFSTRUCT(APPLICATION1) data set MQMDATA.VTS1.SMDS.APPL1 space map has
been rebuilt, message count 10240
```

The queue manager initiates the rebuilding of the shared message data set space map by scanning the coupling facility structure. Upon completion the CSQE255I message is logged showing that there are 10240 messages held on the structure.

Peer level recovery

```
12.14.45 CSQE011I @VTS1 CSQESTE Recovery phase 1 started for structure
CSQSYSAPPL connection name CSQEPRF5VTS101
12.14.45 CSQE013I @VTS1 CSQERWI1 Recovery phase 1 completed for structure
CSQSYSAPPL connection name CSQEPRF5VTS101
12.14.45 CSQE012I @VTS1 CSQERWI2 Recovery phase 2 started for structure
CSQSYSAPPL connection name CSQEPRF5VTS101
12.14.45 CSQE014I @VTS1 CSQERWI2 Recovery phase 2 completed for structure
CSQSYSAPPL connection name CSQEPRF5VTS101
12.14.45 CSQE006I @VTS1 CSQECLOS Structure CSQSYSAPPL connection name
CSQEPRF5VTS101 disconnected
```

Phase 1 of the peer level recovery process involves recovering units of work that were in progress at time of failure.

Phase 2 involves recovering failed queue managers the in-flight messages for that queue manager.

Worked example of restart times

After an abnormal shutdown, extra time is needed to recover the system from the log data sets, to rebuild the system to the point of failure, and then to commit or roll back the work.

In the measurements below, CICS applications put messages to a queue and a batch server program processes the message and puts a reply on the specified reply-to queue. The CICS application then gets the reply and terminates.

A certain number of CICS transactions were run and then the queue manager was cancelled and restarted.

During restart the duration between the start of the queue manager and key restart messages being produced were recorded.

Number of CICS transactions	Time between startup and CSQR001I	Time between CSQR001I and CSQR002I	Time between CSQR002I and CSQY022I
0	7 seconds	1 second	0.2 seconds
10000	7 seconds	59 seconds	0.2 seconds

There is a linear relationship between the time between messages CSQR001I and CSQR002I and the number of CICS transactions that have run between the last checkpoint and the system being cancelled.

If there are ongoing units of work that existed before the latest checkpoint when the system ended, MQ will have to go back further in the log to the start of the units of work, and read the log from that point. This will extend the restart time. This could happen with channels that have a very long BATCHINT time specified, or on which the remote end of a channel has failed and messages are in doubt.

A checkpoint is taken at the following times:

- When an active log fills and switches to the next active log.
- When the number of writes to log buffers (Write Wait + Write Nowait + Write Force in the log manager statistics) exceeds the number specified for the LOGLOAD parameter of CSQ6SYSP. The number of writes to log buffers is reset to zero after a checkpoint.
- When an ARCHIVE LOG command is issued, because this forces a log switch.
- At shutdown.

1000 transactions were run, and the log statistics show that the number of "writes to log buffers" was about 31 000, or 31 "write to log buffers" per transaction. This means that, with a LOGLOAD value of 450 000, we could run $450\ 000 / 31 = 14\ 516$ transactions before a checkpoint occurs. If the system fails just before a checkpoint, the time between restart messages CSQR001I and CSQR002I would be about 85 seconds. (10000 transactions take 59 seconds, so 14516 would take 85 seconds.) This gives a total restart time of about $7 + 85 + 0.2 = 92$ seconds.

Note: Different message sizes might have different numbers of "write to log buffers" per transaction.

Effect of the number of objects defined on start up time

Restart time is affected by the number of objects that are defined because these are read in and validated during startup.

Number of objects defined	Time between startup and CSQR001I	Time between CSQR001I and CSQR002I	Time between CSQR002I and CSQY022I
140	7	1	0.2
4140	7	3.6	0.2
14484	7	7.6	0.2

With 14 484 objects defined, the default allocation of 1050 buffers for buffer pool 0 is too small. After the size of the buffer pool had been increased, the buffer pool statistics showed that 1230 buffers had been used.

Tuning

Performance implications of very large messages

The use of very large messages is likely to impact performance in the following ways:

- Page set I/O is more likely with very large messages than with the same amount of data in smaller messages. Buffer pools are much more likely to be so full that synchronous output to page sets is required. This significantly slows all applications using an affected buffer pool.
- For persistent messages the log I/O load will be great and other smaller messages are likely to be significantly slowed waiting for log I/O or even just space in log buffers. Ensure that log parameter OUTBUFF is set at its maximum (4000).
- Increased virtual storage usage in applications and in the IBM MQ channel initiator.
 - This is likely to cause increased real storage usage in applications and IBM MQ buffer pools.
 - The maximum number of channels all transmitting 100-MB messages is unlikely to exceed 15 because of virtual storage limitations. The use of BATCHSZ(1) is recommended for any channel transmitting very large messages

These considerations could cause an increase in elapsed time and CPU cost for every message in your queue manager compared to using the same amount of data in several smaller messages.

Queue Manager attribute LOGLOAD

What is LOGLOAD?

LOGLOAD is defined as the number of log records written by IBM MQ between the start of one checkpoint and the next.

Checkpoint processing will begin with the first of:

- the LOGLOAD threshold is reached.
- the end of the active log is reached.
- the queue manager is stopped.

What settings are valid for LOGLOAD?

Valid values for LOGLOAD range from 200 up to 16 million log records.

The value of LOGLOAD can be changed by either of the following methods:

- use the SET SYSTEM command. To permanently change this, put the SET SYSTEM command into a data set in the CSQINP2 concatenation.
- update the CSQ6SYSP parameter and regenerate the parameter module.

What is an appropriate value for LOGLOAD?

In our measurements the best performance, in terms of transaction cost and throughput, have been obtained with a LOGLOAD in the range of 4 million to 16 million.

When might a lower LOGLOAD be appropriate?

There may be occasions where a LOGLOAD of less than 4 million may be appropriate to your system, for example:

- When restart time is defined by an SLA. See “[Restart](#)” for more information.
- When using IBM InfoSphere Data Replication for DB2 for z/OS as part of an Active-Active solution and the system uses **multiple outbound IBM MQ channels** defined between the capture and apply queue managers.
 - In this instance we found that a lower LOGLOAD of 100,000 helped reduce instances where one transmission queue might achieve better throughput due to a more favourable log force frequency.

What happens at checkpoint

When a checkpoint is driven, the Deferred Write Process (DWP) will be invoked to write data that has been held in the buffer pool through 2 checkpoints from the buffer pool to the page set. More information can be found in the section titled “[Deferred Write Process](#)”.

Note: There can be a significant difference in the rate that data can be written by DWP depending on the IBM MQ release. We saw an individual DWP writing data to page set at the following rates:

- **V710:** 25MB per second
- **V800:** 300-600MB per second

This increase in write rate in IBM MQ version 8.0.0 is due in part to an increase in the number of pages written per I/O request (from 4 to 16) and also due to the number of parallel I/Os (up to 64), which can have an impact on the I/O subsystems response times.

Impact of LOGLOAD on workload

The value of LOGLOAD can have an impact on the throughput (messages per second) and the cost of those messages in the queue manager address space.

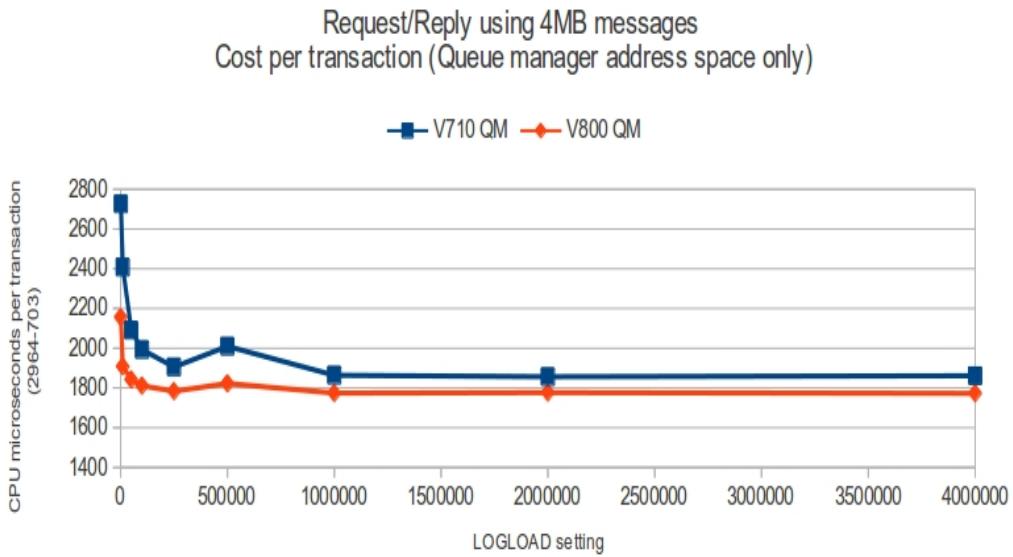
Measurements were run on V710 and V800 queue managers and used the following scenarios:

- **Low queue depth** - request/reply workload where the queue depths are low.
- **High queue depth** - deep queue processing where the queue was pre-loaded with messages and subsequently messages were put and got in random order whilst maintaining a high queue depth.
- **High variance in depth** - sending messages between queue managers using channels. E.g. where the rate that the messages arrive on the transmit queues exceeds the rate at which the messages can be got and sent across the network. This results in the transmit queues changing from empty to deep, until the point where the putting task completes, which then allows the transmit queue depth to drop to 0 as the channel initiator completes sending all of the messages.

Low queue depth

For both the V710 and V800 measurements there was little impact from LOGLOAD with messages up to 100KB.

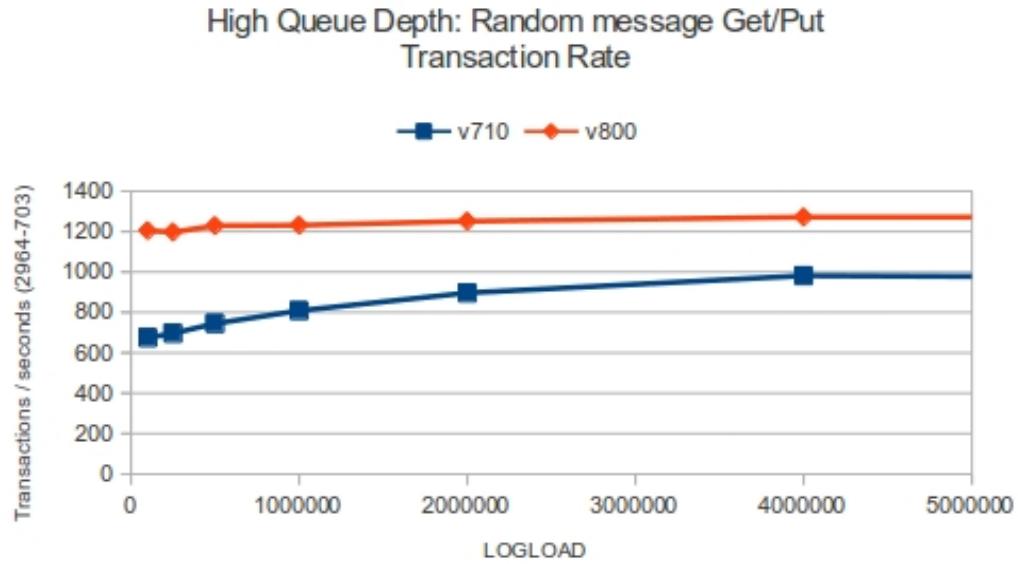
For larger messages, a small LOGLOAD value did impact the cost per transaction in the queue managers' address space and as such, the optimal value for LOGLOAD would be 1 million upwards.



High queue depth

Optimum performance for this workload type was observed when the LOGLOAD was in the range 4 million to 16 million.

The following chart shows the achieved transaction rate with 100KB messages that are randomly got using a CORRELID and then put back to the queue.



In the V710 measurement, the largest impact is to the elapsed time of the MQPUT where it is delayed for log write.

Note: For this workload type, the V800 queue manager is using 64-bit buffer pools and benefits from the more intensive DWP and as a result is less affected by log writes as there are buffers available.

High variance in depth

Optimum performance for this workload type was observed when the LOGLOAD was in the range 4 million to 16 million but there were exceptions which include:

- *Sending data across multiple channels where the applications have a dependency of message ordering across the channels*, such as when using IBM InfoSphere Data Replication for DB2 for z/OS with **V710** queue managers which may benefit from a LOGLOAD at the lower end of the scale. In our measurements a LOGLOAD of 100,000 showed the most reliable performance largely due to reducing the effects of log-forces being skewed towards one channel, resulting in a more even balancing of log writes - which led to messages being sent at similar rates instead, and ultimately meant that messages became available for processing by the apply task sooner. In test measurements this had the effect of reducing the elapsed time for a fixed size workload by 12% when compared with a LOGLOAD in the range 4-16 million.

Impact of LOGLOAD on log shunting

Long running transactions can cause unit of work log records which span log data sets. IBM MQ handles this scenario by using log shunting, a technique which moves the log records to optimize the quantity of log data retained and queue manager restart time.

When a unit of work is considered to be long, a representation of each log record is written further down the log. This is known as “log shunting”.

At each checkpoint, whether triggered by reaching the end of an individual active log or by reaching the LOGLOAD threshold, long running transactions that are eligible for log shunting will be shunted. A smaller LOGLOAD value can impact the number of transactions being shunted and can also increase the amount of data being logged - which in turn can result in the checkpoints driven by a small LOGLOAD value to occur more frequently.

Impact of LOGLOAD on restart

The time taken to start a queue manager can be divided into four parts:

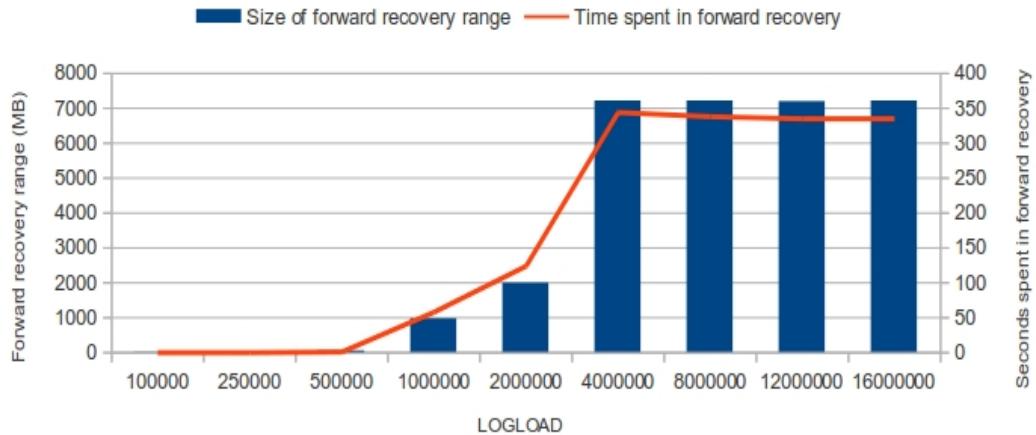
1. The time taken to load the MQ modules and for each component to initialize. Message CSQR001I is issued when this phase is complete.
2. The time taken to process the logs and recover any in-flight work; after a normal shutdown this work is very small. Message CSQR002I is issued when this phase is complete.
3. The time taken to read every object definition from page set 0 and to perform a consistency check on it. Message CSQY022I is issued when this phase is complete.
4. The time taken to process the statements in CSQINP2. Message CSQ9022I is issued when this phase is complete.

The setting of LOGLOAD can affect the amount of work that needs to be completed when processing the logs. The time spent in forwards recovery is largely influenced by the number of pages that need to be read from the page set(s). This is discussed in more detail in the “[How long will each phase of recovery take?](#)” section.

The following chart gives a guide to the recovery times as LOGLOAD increases, resulting in increased reads from page set.

QM Restart: Forward recovery time as more data needs recovering

Measurement on 2964-703 connected to DS8870 DASD where I/O time was 233 microseconds per page



Notes on chart: The proportion of pages read relative to the range of data specified by the CSQR03OI message varies. In this example the variation is between 10% (for LOGLOAD 500,000) and 100% (for LOGLOAD 1,000,000). In these extreme cases the amount of data specified by the CSQR03OI message was not particularly large, i.e. less than 1GB but when LOGLOAD was 4 million or higher, the range of data was 7GB of which 80% required reading, resulting in forward recovery times of 340 seconds.

Use of MQ Utilities

If possible avoid setting MAXUMSGS high. The number of MQ operations within the scope of a single MQCMIT should usually be limited to a reasonably small number. For example, you should not normally exceed 100 MQPUTs within a single MQCMIT. As the number of operations within the scope of one MQCMIT increases the cost of the commit increases non-linearly because of the increasing costs involved in managing very large numbers of storage blocks required to enable a possible backout. So for queues with many tens of thousands of messages it could be very expensive to set MAXUMSGS greater than the number of messages and use CSQUTIL utility functions like COPY or EMPTY.

The V8.0 Administration reference states, in the context of CSQUTIL utilities,

Syncpoints:

The queue management functions used when the queue manager is running operate within a syncpoint so that, if a function fails, its effects can be backed out. The queue manager attribute, MAXUMSGS, specifies the maximum number of messages that a task can get or put within a single unit of recovery.

MAXUMSGS should normally be set to a low value, both to protect against looping applications, and because there might be a very large processor cost in committing many messages.

The utility forcibly takes sync points as required and issues the warning message CSQU087I. If the function later fails, the changes already committed are not backed out. Do not just rerun the job to correct the problem or you might get duplicate messages on your queues. Instead, use the current depth of the queue to work out, from the utility output, which messages have not been backed out. Then determine the most appropriate course of action. For example, if the function is LOAD, you can empty the queue and start again, or you can choose to accept duplicate messages on the queues.

To avoid such difficulties if the function fails, but at the risk of incurring a large processor cost, set MAXUMSGS to be greater than:

- *The number of messages in the queue, if you are working with a single queue.*
- *The number of messages in the longest queue in the page set, if you are working with an entire page set.*

The following should be added:

The number of MQ operations within the scope of a single MQCMIT should usually be limited to a reasonably small value. For instance you should not normally exceed 100 MQPUTs within a single MQCMIT. As the number of operations within the scope of one MQCMIT increases the cost of the commit increases non-linearly. If the CPU cost of using the CSQUTIL utilities with a very high MAXUMSGS becomes a concern and you really need to have the effect of a single commit then you should consider using an intermediate temporary queue and your own simple program with commits every say 50 messages.

For example, consider the requirement to read a sequential dataset of 100,000 records and add each record as a message to an existing non-empty queue. This requires the effect of a single commit as the application cannot be just re-run in the event of failure. In this case it might be better to have simple applications which:

- LOAD the records as messages to a temporary queue with a low MAXUMSGS. The temporary queue can be deleted in the event of failure and the job rerun.
- Copy this temporary queue to the target non-empty queue with 50 MQGETs plus 50 MQPUTs per MQCMIT. This job can be rerun in the event of failure. The temporary queue is deleted on successful completion.
- Alternatively the command MOVE QL(tempq) TOQLOCAL(targetq) TYPE(ADD) may be used.

IBM MQ Utilities: CSQUTIL

The CSQUTIL utility program is provided with IBM MQ to help perform backup, restoration and reorganization tasks and to issue MQ commands.

These tasks include page set management functions including formatting and increasing the size of the page sets.

In order to increase the size of the page set, it is necessary to create the new page set and format it using the FORMAT function and then copy the contents of the existing page set into the new page set, using the COPYPAGE function.

The FORMAT and COPYPAGE functions may be performed within the same CSQUTIL job step or in separate steps.

FORMAT

The FORMAT function is used to format page sets, initializing them such that they can be used by the queue manager. On our system, each gigabyte of data took approximately:

- 0.725 CPU seconds
- 45 seconds elapsed

This means that to format a 4GB page set, it took 2.9 CPU seconds (on a 3-processor 2097-EC64) and 3 minutes elapsed for the job to complete.

The queue manager does have the capability to expand and format a page set whilst it is active, in the situation when it does not have sufficient capacity. In order to perform this expansion, the queue manager will slow any MQPUTs to queues on the page set whilst the expand and format takes place.

COPYPAGE

The COPYPAGE function is used only for expanding page sets to copy one or more page sets to a larger page set. The entire source page set is copied to the target page set, regardless of how many messages there are on the page set.

On our system, copying each gigabyte of page set took approximately:

- 2.53 CPU seconds
- 30 seconds elapsed

This means that to format a 4GB page set, it took 10.12 CPU seconds (on a 3-processor 2097-EC64) and 2 minutes elapsed for the job to complete.

RESETPAGE [FORCE]

The RESETPAGE function is like the COPYPAGE function except that it also resets the log information in the new page sets.

The “**RESETPAGE**” function:

- Does a copy and reset, using a source page set and a target page set.
- The target page set should have been opened previously, preferably using the FORMAT command, otherwise the step may fail with a "CSQU156E GET failed for CSQTxxxx data set. VSAM return code=00000008 reason code=00000074" message.

- The target page set size should be equal to or greater than the current size of the source page set including any expansions. The RESETPAGE function does not have the ability to expand the target page set and instead will fail before attempting the copy.

On our lightly loaded system (3-processor on zEnterprise 196), each gigabyte of page set took approximately:

- 2.13 CPU seconds
- 35 seconds elapsed

This means that to RESETPAGE a 4GB pageset it took 8.5 CPU seconds and 2 minutes 20 seconds for the job to complete.

The “**RESETPAGE FORCE**” function:

- Does a reset in place, using only the source page set.
- This means that the page set will be of the appropriate size.
- As the same page set is being accessed for read and write operations, the rate of reset is significantly lower than the "RESETPAGE" option.

On our lightly loaded system (3-processor on zEnterprise 196), each gigabyte of page set took approximately:

- 4.31 CPU seconds
- 123 seconds elapsed

This means that to RESETPAGE a 4GB pageset it took 17.2 CPU seconds and 8 minutes 15 seconds for the job to complete.

Conclusions for RESETPAGE

- In order to ensure that queue manager down-time is minimised, it is advisable to use "RESET-PAGE" rather than "RESETPAGE FORCE", unless there is insufficient storage for a second set of page sets for the queue manager.
- If multiple page sets are to be reset, they should be processed as separate jobs run in parallel.
- For cost purposes, the "RESETPAGE" function uses approximately 50% of the CPU that the "RESETPAGE FORCE" function.
- Given that these jobs can be long running, it is advisable to check the service class is appropriate and the priority is not degraded over time.

Queue Manager Trace

For guidance on trace options for the channel initiator i.e. trace(chinit), accounting class 4 and statistics class 4, refer to section “[Channel Initiator - trace costs](#)”.

To help understand the data generated by accounting and statistics trace, see SupportPac MP1B “WebSphere MQ - Interpreting accounting and statistics data, and other utilities” which is available at <http://www.ibm.com/software/integration/support/supportpacs/>

Accounting Trace Costs

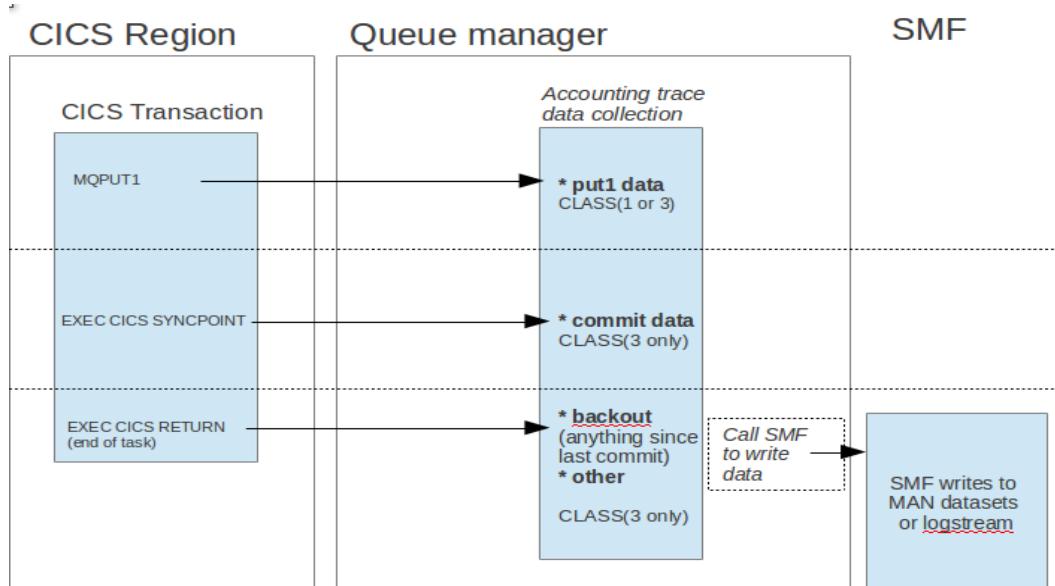
Accounting trace classes 1 and 3 write an SMF 116 record for each transaction.

Additional “continuation” records may be written when class 3 accounting is enabled depending on the number of queues accessed by the transaction. Typically the primary SMF 116 record can support up to 8 queues and each continuation record can support a further 9 queues. For example, an application that accesses 20 queues would see 3 SMF 116 records, one primary and 2 continuation records, the first of which has data for 9 queues and the second has data for the final 3 queues.

The amount of data written to SMF can impact the CPU costs when enabling accounting trace, particularly in an environment with a high transaction rate, as can where the SMF data is stored, for example we have observed that writing high volumes of data to logstreams² is lower cost than writing to SMF MAN datasets.

In a CICS environment with a high transaction rate, the logging of records to SMF MAN datasets may result in the queue manager reporting CSQW133E ‘TRACE DATA LOST’ messages as SMF may not be able to write the data to its datasets sufficiently quickly. In this case it is advisable either to use logstreams rather than SMF MAN datasets or to use TRACE(A) CLASS(3) for short periods of time (60 seconds).

Consider a CICS transaction that performs a single MQPUT1 followed by an EXEC CICS SYNCPOINT and EXEC CICS RETURN when the connected queue manager has accounting trace enabled:



²SMF write rates are discussed in section “IBM MQ and zEnterprise Data Compression (zEDC)”

The diagram attempts to show when the queue manager will gather accounting data.

- Accounting data will be stored for the MQPUT1 for either class 1 or 3.
- When trace class 3 is enabled:
 - EXEC CICS SYNCPOINT will result in the queue manager storing “commit” data.
 - EXEC CICS RETURN will result in the queue manager storing “backout” and “other” data relating to the end of task processing. **Note:** The action performed under the IBM MQ accounting data type “backout” is not actually backing out, rather a resetting of the transaction state within the queue manager.
- At transaction end, the queue manager calls SMF to request the data be written to the SMF data repository (MAN datasets or logstreams).

Storage Usage

Prior to MQ version 8, MQ would initialise certain accounting data areas regardless of the class 3 accounting trace status. Enabling class 3 accounting would cause further data areas to be allocated as well as driving the writing of the data to SMF.

From MQ version 8 onwards, the storage used for accounting is only allocated when class 3 accounting is enabled.

The total storage used per connection for accounting trace class 3 is usually between 4KB and 8KB but can be higher when a connection accesses many queues.

Who pays for data collection?

Typically there is an increase in the costs attributed to the application address space.

Class 3 accounting may also see an increase in the costs attributed to the queue manager address space.

Who pays for writing to SMF?

There is typically an increase in CPU usage in the SMF address space, which is dependent on the amount of data written in each SMF 116 record.

Class 3 accounting may also see an increase in the queue manager address space for the aggregation of task related data.

How much data is written?

Accounting trace class 1 typically writes 436 bytes per transaction, regardless of the number of queues accessed by the transaction.

Accounting trace class 3 data will depend on the number of queues used but as a guide, a transaction accessing 2 queues typically writes 8324 bytes.

A class 3 SMF 116 record with 8 queues would typically write 25076 bytes.

This means that for storing data for 1,000,000 transactions the following storage would be required:

- class 1: 415MB
- class 3 with 2 queues: 7938MB

- class 3 with 8 queues: 23914MB

Trace(A) CLASS(1) costs: TRACE(A) CLASS(1) can be estimated as:

- ***Data gathering:***
 - 2 microseconds per API (MQPUT, MQPUT1, MQGET only)
- ***Writing to SMF:***
 - plus 1-5 microseconds. The record is fixed length and is relatively small keeping costs down.

Trace(A) CLASS(3) costs: The costs for TRACE(A) CLASS(3) can be estimated as³:

- ***Data gathering:***
 - 1-3 microseconds per API (including commit, backout and other)
- ***Writing to SMF:***
 - plus 6-50 microseconds for the primary SMF record (depending on size), lower costs were observed when fewer queues were accessed)
 - plus up to 60% of the cost of writing the primary SMF record for each continuation record, again depending on how many queues the continuation record contains.

³Based on measurements on zEC12.

Comparing costs – a working example: Consider a CICS transaction that costs 1 millisecond (1000 microseconds) and performs the following interactions with an MQ queue manager:

MQPUT1	
COMMIT	as a result of EXEC CICS SYNCPOINT
BACKOUT	as a result of EXEC CICS RETURN
OTHER	as a result of EXEC CICS RETURN

Enabling **class 1 accounting trace** would be expected to add the following cost to the transaction:

MQPUT1	+2 microseconds.
Writing to SMF	+3 microseconds.
Total	1005 microseconds (+0.5%)

Enabling **class 3 accounting trace** would be expected to add the following cost to the transaction:

MQPUT1	+2 microseconds.
COMMIT	+2 microseconds.
BACKOUT	+2 microseconds.
OTHER	+2 microseconds.
Writing to SMF	+25 microseconds

Total	1033 microseconds (+3.3%)
-------	---------------------------

Accounting trace considerations

- The impact of accounting trace will depend on what proportion of the transaction is weighted towards MQ – for example if a transaction spends 50% of its lifetime in MQ, the impact of trace may be much higher than those in the preceding examples.
- By contrast a transaction that performs DB2 SQL, reading and writing of files and complicated calculations may see a small impact from accounting trace.
- The size and persistence of the message being put or gotten does not impact the cost of accounting trace.
- Class 3 accounting in a high transaction environment can generate vast amounts of data. It can be useful to enable this trace periodically to monitor your systems.

Statistics Trace Costs

TRACE(S) costs are not significant as they are not dependent on transaction rate nor transaction volumes.

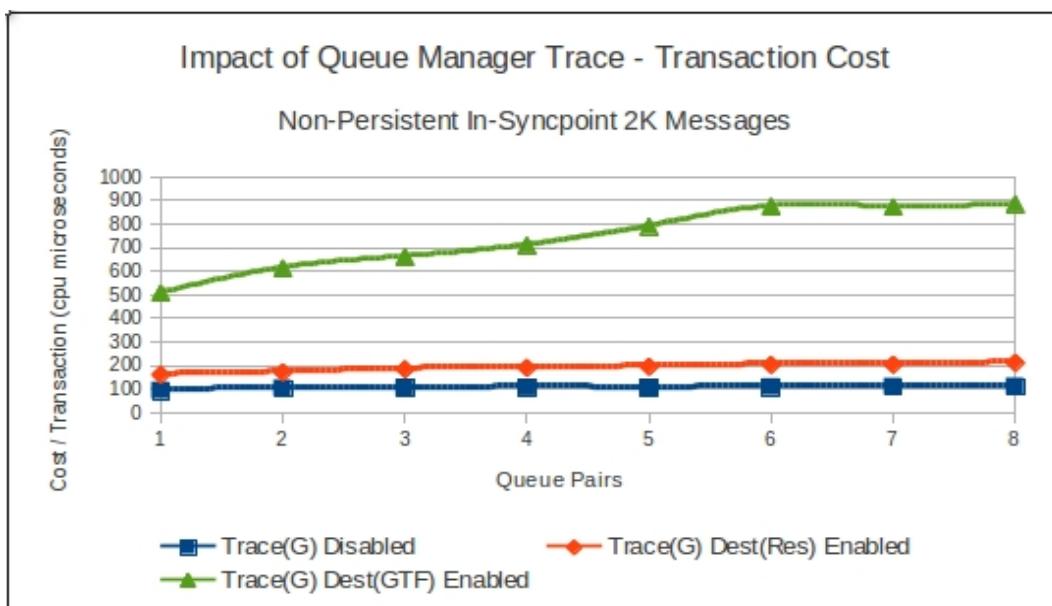
Global Trace Costs

NOTE: From a performance perspective, disabling TRACE(G) is advised as the global trace costs vary significantly depending on the MQ workload being processed.

WebSphere MQ for z/OS version 7.1.0 changed how the queue manager global trace is gathered. In previous releases, the global trace data was stored in a single storage area which on a busy system with multiple processors could result in a high degree of contention when writing the trace data. Version 7.1.0 exploits 64-bit storage to allocate an area of storage for each thread, which reduces the contention issues seen previously.

The destination of the trace can have a significant affect on the performance achieved when running with trace enabled.

The following 2 charts show the impact of running with TRACE(G) enabled in an LPAR with high workload, low resource contention from an MQ perspective, i.e. workload is spread out over multiple queues that are hosted on multiple pagesets with multiple buffer pools, only a single pair of requester/server applications accessing each pair of queues.

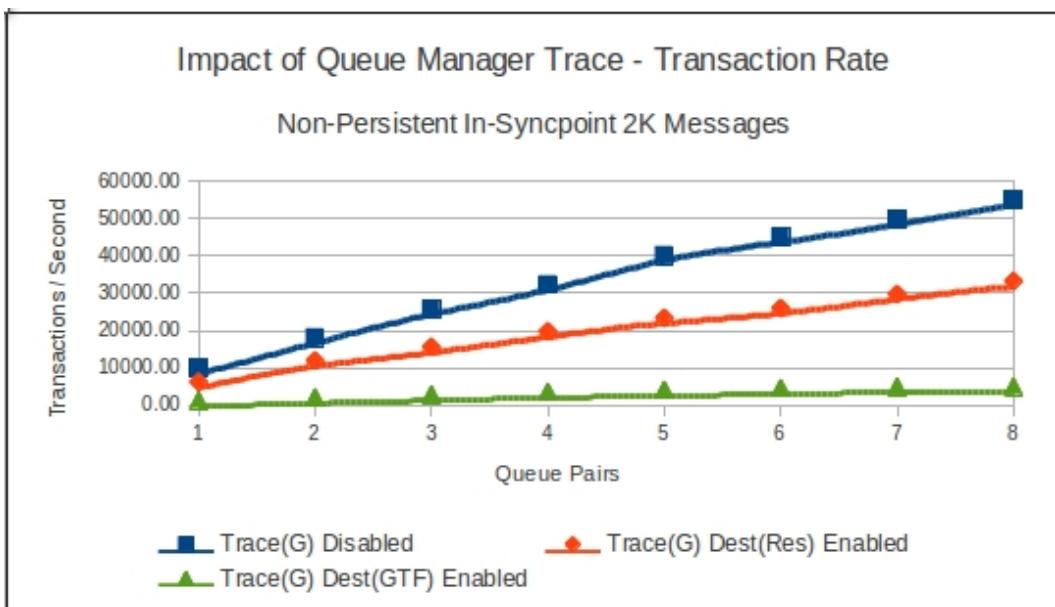


The first chart compares the cost per transaction when attempting to process messages in a request/reply type scenario where the server messages are processed inside of syncpoint, i.e. the server gets and puts its messages in-syncpoint.

NOTE: This transaction cost is the cost incurred by the requester application, the server application and the queue manager address space. The applications used are performing very little non-IBM MQ related workload.

- When TRACE(G) is off, the transaction cost is relatively flat at approximately 100 microseconds.
- When TRACE(G) with DEST(RES) enabled, the effect of global trace doubles the transaction cost.
- With TRACE(G) DEST(GTF) the transaction cost increases significantly to more than 8 times the cost of running with global trace disabled.

The subsequent chart shows how the achieved transaction rate is affected by global trace.



The above chart shows how the achieved transaction rate are constrained much sooner when TRACE(G) is enabled, especially with destination GTF selected. A significant proportion of the time is spent waiting for serialization to process the trace records.

Performance / Scalability

Maximum throughput using persistent messages

You should consider whether you really need persistent messages. Many applications do not require the advantages of persistent messages, and can make use of the cheaper, faster non-persistent messages instead. Some users do not use persistent messages at all!

If you use persistent messages then allocate your log data sets on your best DASD.

What factors affect persistent message throughput ?

The extra factor affecting throughput of persistent rather than non-persistent messages is the performance of the IBM MQ log, which depends on the following:

- Type and overall usage of the DASD subsystem used for the MQ log data sets.
- The data rate that the DASD subsystem can sustain for the IBM MQ log data sets. This sets the upper limit for the IBM MQ system.
- The DASD subsystem and control unit type, the amount of DASD cache, and the number of channel paths to the DASD. All will have an effect on throughput.
- Total I/O contention within the system.
- IBM MQ log data set placement. Having logs on heavily used DASD volumes can reduce throughput.
- The average time to complete an I/O to the DASD volume, which depends on the amount of data to be logged as well as the DASD subsystem characteristics and IBM MQ log data set placement. Using zHPF may provide some relief in this instance – see “[Benefits of using zHPF with IBM MQ](#)”

See “[Maximum persistent message throughput – private queue](#)” for an example of the rates achieved.

Application syncpoint specifics

- The rate of commits or out of syncpoint requests. This is application specific. Each commit or out of syncpoint request involving a persistent message requires the application to wait for completion of an MQ log I/O (a log force). A two-phase commit requires the application to wait for the completion of two separate MQ log I/Os (2 log forces).
- The worst case is 2 MQ log forces for each MQPUT and each MQGET. For instance.
 - Consider a CICS application might update a recoverable VSAM file and MQPUT a message in one unit of work. This requires a 2-phase commit and therefore 2 MQ log forces.
 - That message is then processed (MQGET) by a DB2 stored procedure which updates a database and commits the unit of work. This requires a 2-phase commit coordinated via RRS and therefore 2 MQ log forces.
- Another case is 1 log force for each MQPUT and each MQGET. For instance consider
 - A channel receiving messages at an achieved batchsize of 1, MQPUTs each message and commits the batch (this is typical for a channel unless deliberate batching of messages or a very high message rate occurs). This requires a 1-phase commit.

- A CICS program MQGETs this message, updates a DB2 database, MQPUTs a reply message then commits. This requires a 2-phase commit.
- A channel MQGETs and sends the reply message back to the originator at an achieved batchsize of 1. This requires a 1-phase commit.
- Thus there are 4 MQ log forces for the 2 messages processed, which is an average of 1 log force per MQPUT and MQGET.
- Because each application using persistent messages is likely to be I/O-bound on the log you will probably need many application instances to achieve best throughput.
- However, some applications require strict message ordering. This means only a single application instance is allowable.

Message size and number of messages per commit

Message size and number per commit affect the amount of data which must be written to the log for each log force.

Similar amounts of data per commit will usually give similar throughput. For example, 5 persistent messages of size 1KB require about 11.5KB of data to the log when fully processed by MQPUT and MQGET. 1 persistent message of size 10KB requires a similar amount of log data. Similarly 50 persistent messages of size 1KB which are MQPUT in one unit of work and MQGET in one unit of work will have similar IBM MQ log performance as one persistent message of 100KB.

Indexed Queues

Indexed queue considerations

If a non-indexed queue contains more than a few messages and an MQGET with a specific MSGID or CORRELID is used then costs can be very high as the queue will have to be searched sequentially for the matching message. Clearly any queue used by an application that requires specific MQGETs should be specified with the appropriate INDXTYPE.

Prior to version 7.0.1, queue indexes were maintained in 31-bit queue manager storage. This meant that there was an implementation limit as to how many messages could be stored on an indexed queue and on our systems this was around 7.2 million messages. From version 7.0.1 of WebSphere MQ for z/OS onwards, indexed queue data is maintained in 64-bit storage and the queue manager is able to store in excess of 100 million messages on indexed queues.

The amount of storage used for each message on an indexed queue is 272 bytes of above bar storage.

These indexes must be recreated during queue manager initialization for all persistent messages in each indexed private queue. This requires that the first page of all the messages for each indexed queue be read from the pagesets. This is done sequentially queue by queue. For private indexed queues this will increase initialization elapsed time by the order of a few milliseconds per page read. For instance, a private indexed queue consisting of 8 million persistent messages increases elapsed time of initialization by about 280 seconds using DS8000 DASD.

Further details about 64-bit indexes can be found in Performance report [MP1G](#).

QSGDISP(SHARED) indexed queues have indexes implemented within the CF list structure and so do not require recreation at queue manager initialization. The maximum number of messages in a

QSGDISP(SHARED) indexed queue is limited only by the maximum number of messages possible in a CF list structure.

Private indexed queue rebuild at restart

Private indexed queues have virtual storage indexes which must be rebuilt when a queue manager restarts. IBM MQ allows these indexes to be rebuilt in parallel and offer the “[QINDBLD \(WAIT/NOWAIT\)](#)” CSQ6SYSP parameter. The WAIT option gives previous release behaviour and is the default whereas, NOWAIT allows initialization to complete before the index rebuilds complete.

Thus NOWAIT allows all applications to start earlier. If an application attempts to use an indexed queue before that queue's index is rebuilt then it will have to wait for the rebuild to complete. If the rebuild has not yet started then the application will cause the rebuild to start immediately, in parallel with any other rebuild, and will incur the CPU cost of that rebuild.

Each index rebuild still requires that the first page of all the messages for that indexed queue be read from the page set. The elapsed time to do this is of the order of a few milliseconds per page read. Buffer pool page usage is not significantly affected by the index rebuild. Thus other applications will not be impacted by buffer pool contention with index rebuilds.

Up to ten separate index rebuilds can be processed in parallel plus any rebuilds initiated by applications.

Queue manager initiated expiry processing

If the queue manager attribute EXPRYINT is non-zero then at startup and subsequent EXPRYINT second intervals any messages whose expiry time has been passed will be deleted by a system process. EXPRYINT can be changed, including to or from zero using an ALTER QMGR command. The default for EXPRYINT is zero, which gives the previous release behaviour of no queue manager initiated expiry processing. Minimum non-zero EXPRYINT is 5 seconds.

The “[REFRESH QMGR TYPE\(EXPIRY\) NAME\(.....\)](#)” command requests that the queue manager performs an expired message scan for every queue that matches the selection criteria specified by the NAME parameter. (The scan is performed regardless of the setting of the EXPRYINT queue manager attribute.)

For private local queues this system process uses significantly less CPU time than employing your own application to browse complete queues. This is partly because the system knows when there is no possibility of there being any expired messages on a private local queue and because if it is necessary to browse a queue, the system process avoids the overheads involved in repeated calls across the application/system boundary. For the case where the system knows there are no messages to expire on any private queue the CPU cost at each scan is not significant.

For shared local queues each defined queue must be processed. A single queue manager, of those with non-zero EXPRYINT in the queue sharing group, will take responsibility for this processing. If that queue manager fails or is stopped or has its EXPRYINT set to zero then another queue manager with non-zero EXPRYINT will takeover. The CPU cost at each EXPRYINT interval will depend on a number of factors:

- Number of messages on queue (all messages including those with expiry not set will be scanned) as the message may be put by a different queue manager in the QSG).
- Size of message on queue

- Where the message is stored

For example, for 1KB messages on a shared queue, the cost is of the order 9-12 CPU microseconds (2817-703) per each message. This cost increases to 10-20 CPU microseconds (2817-703) when the system actually browses and deletes the expired messages.

If the message has been offloaded to DB2 or shared message data sets, the cost may be higher. For example, when 1KB messages are offloaded to shared message data sets, the cost to determine whether the message can be expired is double that of a message stored solely in the coupling facility.

The time to browse a queue and delete any expired messages will be significantly less than using your own equivalent application because this system process avoids the overheads involved in repeated calls across the application / system boundary.

Queue manager security

How much storage is used?

When a IBM MQ queue manager on z/OS is started and the security switch profiles have been defined such that user-ids need to be authenticated, there is a cost to the queue manager to use this authentication information.

WebSphere MQ for z/OS version 7.0.1 introduced the use of 64-bit storage for holding security information relating to IBM MQ. All storage used by the security manager is now held in 64-bit storage, which means that the ECSA usage does not increase as more user IDs or IBM MQ resources are used. As a result, the number of user IDs that can access IBM MQ resources is limited by the amount of auxiliary storage.

The environment being measured

The measurements were run on a system configured as shown below:

- A 2097 with 8 CPUs available running z/OS 1.11
- A version 7.0.1 WebSphere MQ queue manager with security enabled.
- A CICS region running CTS 3.2
- A number of transactions have been created e.g.
 - A transaction ran an application to put a 1K non-persistent message to a named queue and then get the message from the same queue.
- WebSphere Studio Workload Simulator for z/OS (formerly known as “TPNS”) was used to drive a workload through the CICS environment.
 - TPNS scripts were created to log onto CICS using security and then run a number of transactions using between 1 and 50 MQ queues. This process was repeated for a range of user-ids.

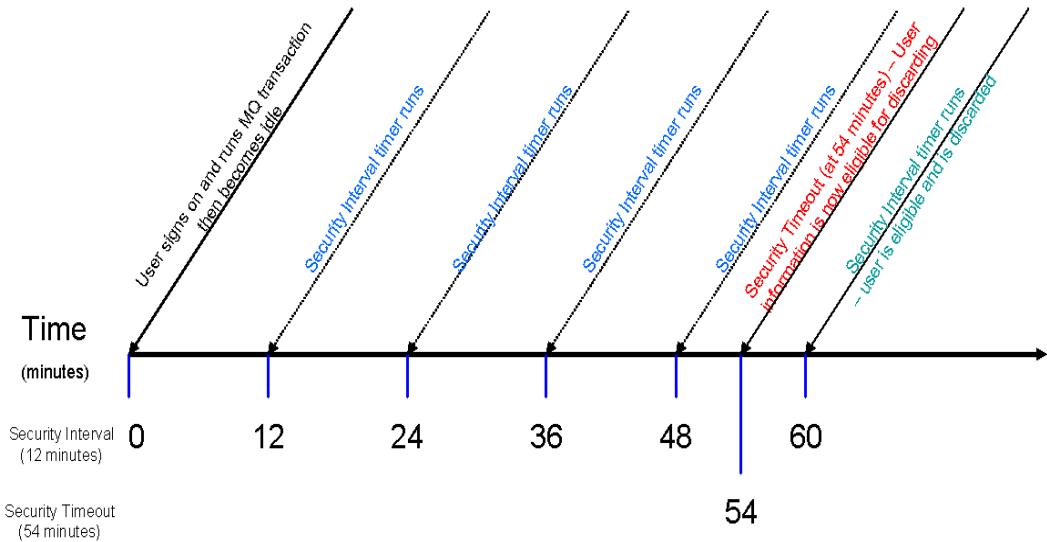
Issuing a “[DISPLAY SECURITY](#)” command against the queue manager shows:

```
CSQH015I MQPZ Security timeout = 54 minutes
CSQH016I MQPZ Security interval = 12 minutes
CSQH030I MQPZ Security switches ...
CSQH034I MQPZ SUBSYSTEM: ON, 'MQPZ.NO.SUBSYS.SECURITY' not found
CSQH034I MQPZ CONNECTION: ON, 'MQPZ.NO.CONNECT.CHECKS' not found
CSQH034I MQPZ COMMAND: ON, 'MQPZ.NO.CMD.CHECKS' not found
CSQH034I MQPZ CONTEXT: ON, 'MQPZ.NO.CONTEXT.CHECKS' not found
CSQH034I MQPZ ALTERNATE USER: ON, 'MQPZ.NO.ALTERNATE.USER.CHECKS' not found
CSQH034I MQPZ PROCESS: ON, 'MQPZ.NO.PROCESS.CHECKS' not found
CSQH034I MQPZ NAMELIST: ON, 'MQPZ.NO.NLIST.CHECKS' not found
CSQH034I MQPZ QUEUE: ON, 'MQPZ.NO.QUEUE.CHECKS' not found
CSQH034I MQPZ COMMAND RESOURCES: ON, 'MQPZ.NO.CMD.RESC.CHECKS' not found
CSQH022I MQPZ CSQHPDTC 'DIS SEC' NORMAL COMPLETION
```

The “security timeout” refers to the number of minutes from last use that the information about a user ID is retained by IBM MQ.

The “security interval” is the time that passes between an MQ process checking the last use time of all authenticated user IDs to determine whether the security timeout period has passed. If the timeout period for a user is exceeded, the information is discarded by the queue manager.

The following time-line attempts to indicate when security-related timer processing will be invoked.



The chart shows that when the security interval is 12 minutes, there is a timer running every 12 minutes to determine whether there are any unused user IDs that are eligible for discarding.

It is not until 54 minutes after the user has signed on and completed their last IBM MQ transaction that they are eligible for discarding.

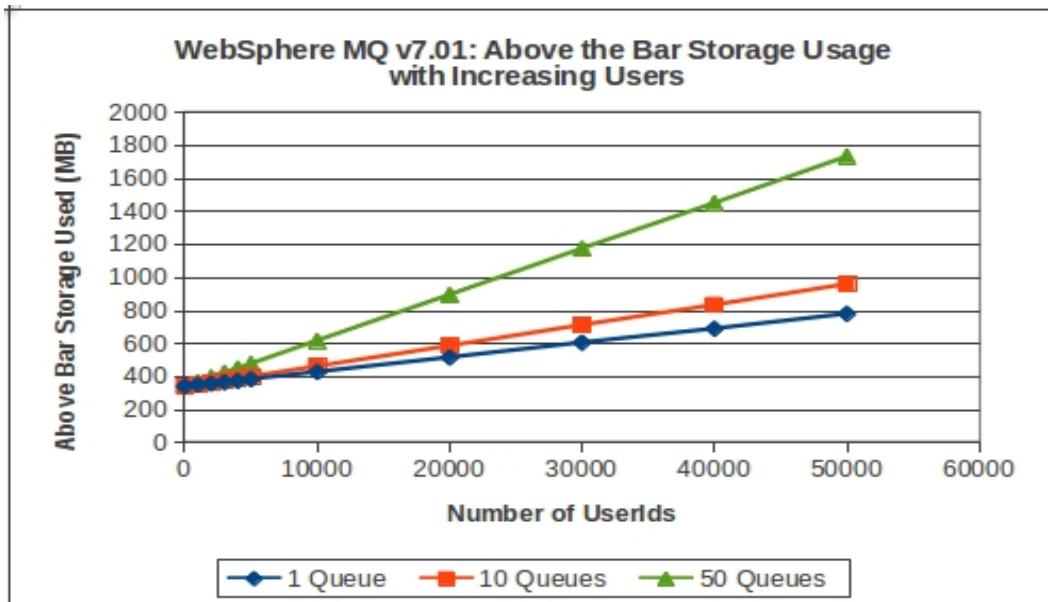
Since the interval runs every 12 minutes, there is a period (in this example) of 6 minutes where the user id is eligible for discarding but is not discarded.

At 60 minutes after completing their MQ transaction, the users' information is discarded from MQ.

From version 7.0.1 of Websphere MQ for z/OS, the Security Manager uses a pooling principle so that when the users' information is discarded, the storage is returned to a pool for subsequent re-use.

The data

The following chart shows the amount of additional virtual storage required when security has been enabled on the queue manager.



Notes on chart:

1. The line titled “1 Queue” is where the TPNS script will run
 - CICS Sign-on followed by 1 transaction putting and getting a non-persistent message for each user id (up to 50,000 unique user ids).
2. The line titled “10 Queues” is where the TPNS script runs:
 - CICS Sign-on followed by 10 serialised transactions putting and getting non-persistent messages from separate queues for each user id (from 1 to 50,000 unique user ids).
3. The line titled “50 Queues” is where the TPNS script runs:
 - CICS Sign-on followed by 50 serialised transactions putting and getting non-persistent messages from separate queues for each user id (from 1 to 50,000 unique user ids).

What can we gather from the chart?

When the user is just issuing a sign-on to CICS followed by a single transaction involving MQ, there is an associated cost of approximately 8.8KB per user of auxiliary storage which includes storage for 1 queue. This is approximate since the 64-bit storage is allocated 1MB blocks.

When the user performs other MQ transactions that affect further queues, additional security information is cached so the storage usage increases. For example when the users workload affects 50 MQ queues, there is a cost of 28.2KB per user of auxiliary storage; an increase of 19.4KB per user.

This means that there is a base cost per user of 8.80KB (which includes accessing 1 queue) when running with security enabled as per the display security command shown previously. Additionally there is a 405 byte cost for each subsequent queue that the user hits as part of their work.

Virtual storage usage

When migrating IBM MQ on z/OS from version 7.x to version 8.0.0 the private storage usage is similar. This section shows the usage and gives some actions that can be taken to reduce storage usage.

From version 8.0.0, the following enhancements relate to storage:

- 64-bit storage used for:
 - Buffer pools (optionally)

From version 7.1.0, the following enhancements relate to storage:

- 64-bit storage used for:
 - Topic Manager
 - Security Manager
 - Indexed Queues
 - Intra-Group Queueing Buffer
 - CFLEVEL(5) shared message data set (SMDS) offload capability
 - CHLAUTH cache

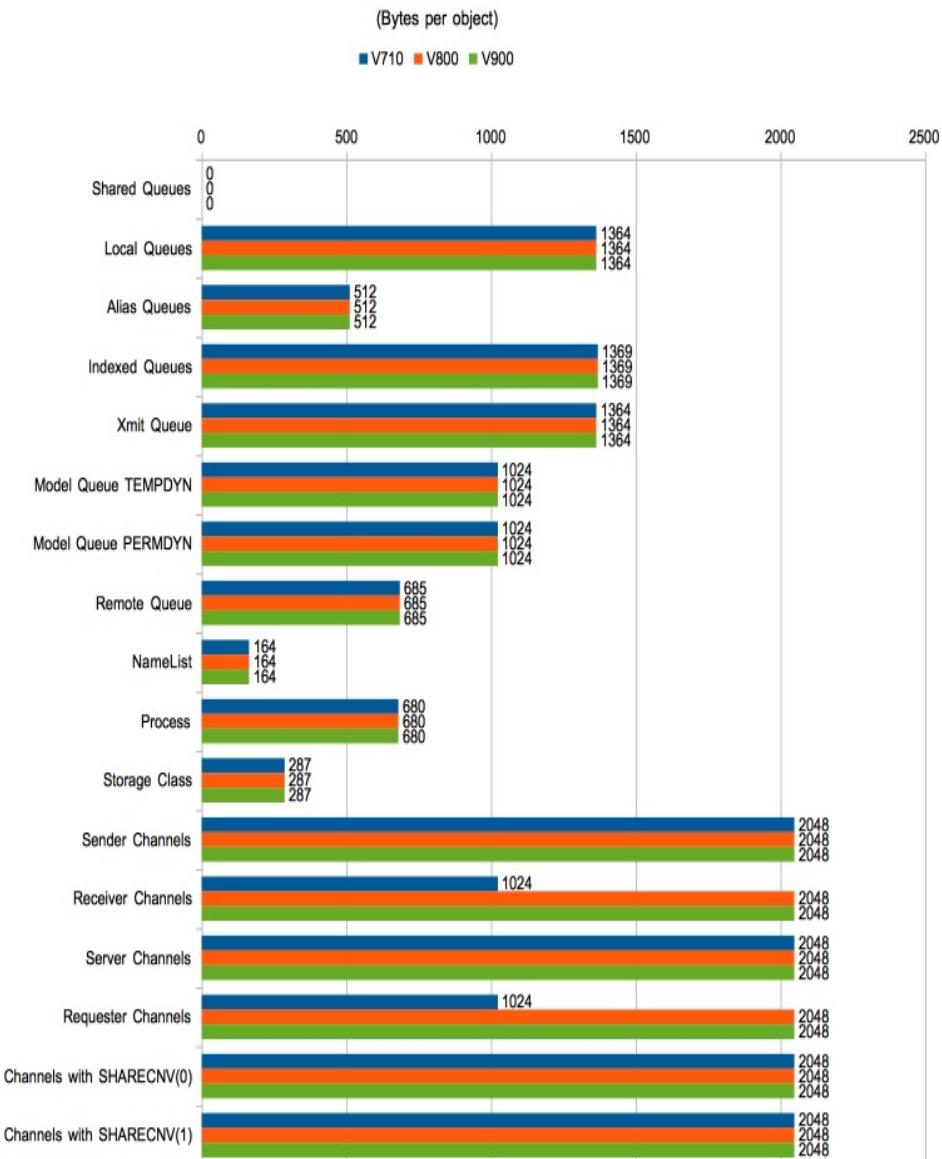
Object sizes

When defining objects the queue manager may store information about that object in pageset 0 and may also require storage taken from the queue manager's extended private storage allocation.

The data shown in the following 2 charts only includes the storage used when defining the objects.

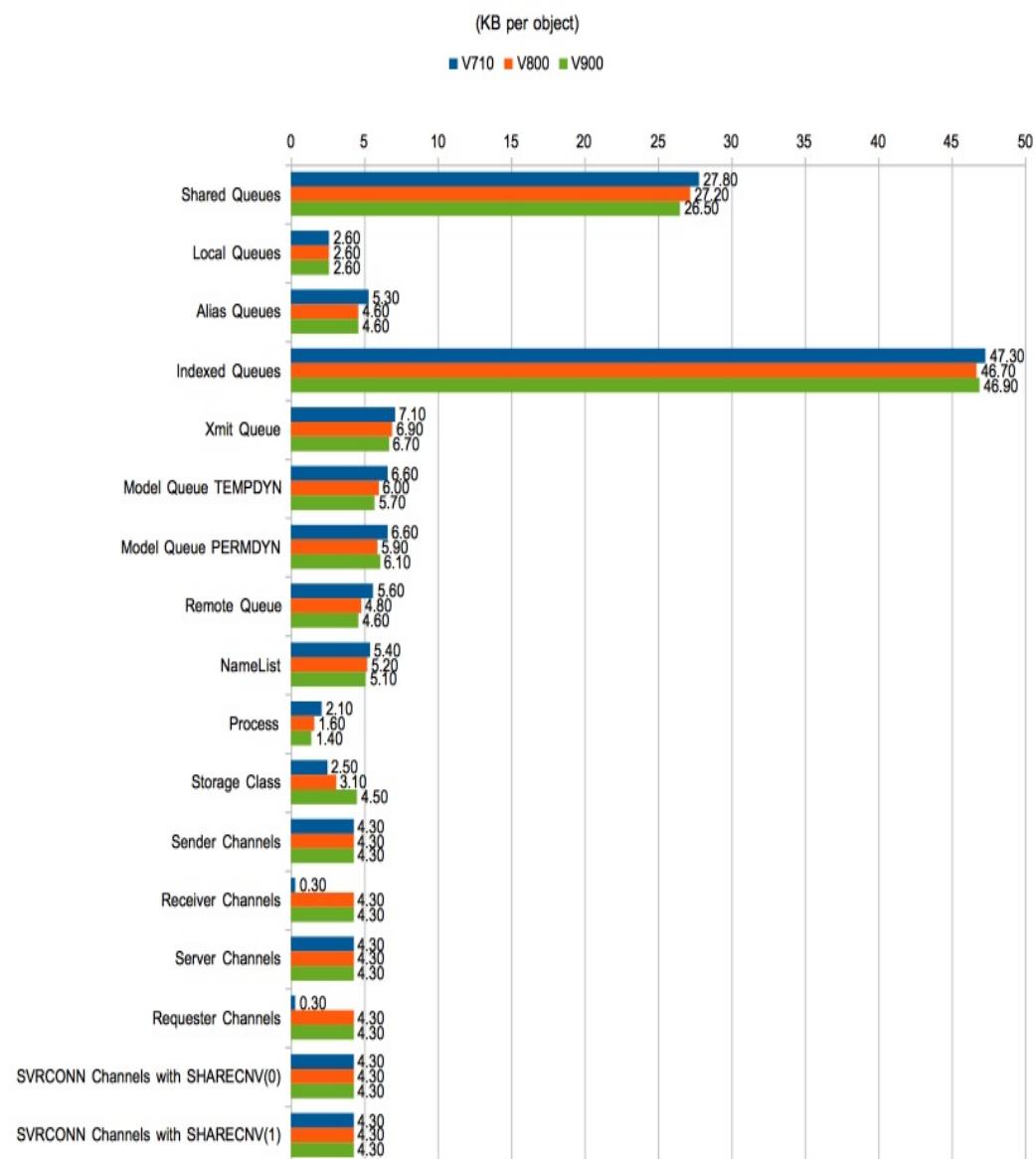
Page set 0 usage

PageSet(0) usage within Queue Manager by object type



Virtual storage usage by object type

Extended Private Storage usage within Queue Manager by object type



NOTE: CHLAUTH objects are cached in 64-bit storage.

Initial CSA (and ECSA) usage

CSA usage is similar between V710, V800 and V900 when similarly configured queue managers are started. On our systems this is approximately 6MB per queue manager.

CSA usage per connection

CSA usage has seen little change in the following releases: V710, V800 and V900:

- For local connections, MCA channels and SVRCONN channels with SHARECNV(0), CSA usage is 2.45KB per connection.
- For SVRCONN channels with SHARECNV(1), CSA usage is approximately 4.9KB per connection.
- For SVRCONN channels with SHARECNV(5), CSA usage is approximately 2.9KB per connection (based on 5 clients sharing a channel instance).
- For SVRCONN channels with SHARECNV(10), CSA usage is approximately 2.9KB per connection (based on 10 clients sharing a channel instance).

Buffer Pool Usage

Typically the buffer pools have used the most virtual storage in the queue manager. Version 8.0.0 allows the buffer pools to be defined using 64-bit storage. This means that there is more space available in the queue manager's 31-bit storage for other things that haven't been moved above the bar, e.g. more handles.

Version 8.0.0 also allows more buffer pools such that a 1:1 mapping with the page sets is possible, allowing a more granular level of control of the sizing of buffer pools according to the usage.

Provided sufficient 64-bit storage is available, you may be able to define the buffer pools as large as the associated pageset.

If storage is limited, you should have a large buffer pool for the short-lived messages, where short-lived is typically a few minutes duration, and a small buffer pool for long-lived messages.

You may be able to reduce the size of buffer pools and maintain good performance, but your performance may degrade if you have an unexpected spike in message throughput which causes your buffer pool to fill up and have less than 15% free buffers. You can monitor the QPSTCBSL fields in the QPST statistics for this.

Storage for security information

From version 7.0.1 Security Manager was changed to use 64-bit storage to hold the security information. Additionally, the storage obtained is not released until queue manager termination, rather the storage used following a user ID being discarded is returned to a storage pool for subsequent re-use. When queue level security is enabled:

- Each user-id which accesses the queue manager requires about 8.8KB of auxiliary storage. Typically 4.66KB of the 8.8KB are "backed" in real storage.
- For each permanent queue that a user uses, then on average it uses 405 bytes per queue.

As all security storage is held in 64-bit storage, the queue manager should not be constrained for storage due to the number of user IDs held.

It is still advisable to set the Queue Manager Security keywords Interval and Time-out to limit the duration that user ID information is cached in the queue manager. The Time-out value specifies how long an un-used user ID can remain in the queue manager. The default time is 54 minutes. Reducing this time will cause unused information to be discarded, returning the storage to the pool. The interval is the duration between checking to see if the time out value has expired.

Impact of number of objects defined

At startup all of the object information is loaded into buffer pool zero. If this buffer pool is large enough to contain all of the objects, then the control blocks for the object stay resident. If buffer pool zero is too small then unused objects will be removed from the buffer pool (but will still be present on disk, and will be read into the buffer pool if the object is used).

The average storage used for local queues is about 2660 bytes per object. This was determined from the storage increase when 10,000 local queues were defined, divided by 10,000. This figures included wasted space in a 4K page when the objects do not fit perfectly.

If you are constrained for storage you can decrease the size of buffer pool to have enough space for the active objects + 20%. Once the system has started and warmed up, then there should be few pages read from the page set.

Use of indexed queues

When a queue is defined as being indexed then additional control blocks are created to define the index. For each queue with indxtpe specified, 47KB of memory are required.

From WebSphere MQ version 7.0.1, the index data for an indexed queue is stored above the 2GB bar. This removes the constraint within the queue manager relating to the depth of an indexed queue over a non-indexed queue.

Object handles

When an application has a queue open, then a handle control block is allocated within the queue manager. This uses about 4K of memory per handle. If there are many concurrent applications, or applications have a large number of open queues then this can lead to a large number of handles.

For example if you have 10,000 client applications, and each client application gets from a queue and puts to a reply queue, then there will be 20,000 handles using 80MB of virtual storage. An MCA channel can have up to 30 queues open at a time, for example when messages from a remote queue manager are being sent to different queues. With 1000 channels, this could be up to 30,000 handles or 120MB, though typically a channel only puts to a few queues.

Number of pages in use for internal locks

Locks are taken by the queue manager to serialize usage of the data and resources. Large messages or large number of messages in a unit of work can lead to a large number of locks being used.

You can reduce the storage required by ensuring that the applications are well behaved:

- Do not process large number of messages in a unit of work. You can use the queue manager attribute MAXUMSGS to limit the number of messages processed in a unit of work.

- Process small numbers of large messages in a unit of work. When moving messages over channels, you might consider using channel attribute **BATCHLIM** to restrict the size of the unit of work for large messages without impacting the batch size when messages are smaller.. Fast (non-persistent) messages are processed out of syncpoint, so the locks are released when the put has completed.

Shared queue

There is increased memory use when a queue manager is used in a QSG. When a queue manager is configured to be part of a Queue Sharing Group, it uses an additional 27MB of storage in the private region.

For each application structure that is used, the queue manager uses 800KB of virtual storage in the private region, 2KB of ESQA and 4KB of ECSA.

Using BACKUP CFSTRUCT command

The BACKUP CFSTRUCT command allocates 65MB. This remains allocated until the system detects that the queue manager is short of virtual storage, and releases any unused storage.

Clustering

If you are using clustering then information about the status of clustering is held both in the channel initiator and the queue manager. The queue manager has two views of the cluster cache, one in key 7, for the queue manager, and one in key 8 for the cluster workload manager applications.

The minimum cache size is 2MB (or 4MB for both copies). The cache size will be calculated dynamically from the configuration, rounded up to the nearest MB and have 1MB extra added. If your configuration changes significantly then this cache can fill up. If using a static cache, the queue manager must be restarted to extend the cache size. If using dynamic cache, the cache will be extended automatically and dynamically (no queue manager restart is required).

Chapter 2

Coupling Facility

CF link type and shared queue performance

Shared queue performance is significantly influenced by the speed of Coupling Facility (CF) links employed. There are several different types of CF links. These include (see the result of a ‘D CF’ operator command).

Link Type		Maximum Operating Rate	Distance
CFP	Coupling Facility Peer Or InterSystem Channel-3 (ISC-3)	200 Megabytes per second.	Up to 20KM unrepeated. Maximum 100KM.
CBP	Integrated Cluster Bus	1500 Megabytes per second.	Up to 10 metres although 3 metres of this is used for internal routing and cable strain relief. Last supported on z10.
PSIFB	Parallel Sysplex coupling over InfiniBand	Rate varies on hardware and link type: 12x IFB3, 12x IFB or 1x IFB. E.g. 5 Gigabytes per second on z13 12x IFB3 1 Gigabyte per second on z13 using 12x IFB.	Up to 150 metres.
CS5	Coupling Short distance 5	z13 only: 6 Gigabytes per second for 0-70 metres, 3.7 Gigabytes per second for 70-150 metres.	Maximum 150 metres..
ICP	Internal Coupling Facility Peer	Fastest connectivity using memory to memory data transfers.	Same box, 8.5 Gigabytes per second on z13.

NOTE: Further information on coupling links can be found in section “Link Technologies” in document “[Coupling Facility Configuration Options](#)”

All link types can be present. The operating system generally selects the fastest currently available.

Some uses of the CF are normally synchronous in that they involve what is effectively a very long instruction on the operating system image while a function request and its associated data are passed over the link, processed in the CF, and a response returned. CPU time for synchronous CF calls is thus to some extent dependent on the speed of the CF link. The slower the link the higher the CPU cost. The faster the CPU the higher the equivalent instruction cost.

System z has heuristics which allow it to change potentially synchronous CF calls to asynchronous. This limits potentially rising CPU costs but can affect throughput as more CF calls become asynchronous.

CF processor time is also dependent on the speed of the CF link, but much less so than the operating system.

All these factors can make prediction of shared queue performance on other systems based on results in this document less accurate than for private queue.

Faster links will generally improve CPU cost and throughput.

How many CF structures should be defined?

A minimum of two CF structures are required. One is the CSQ_ADMIN structure used by IBM MQ. All other structures are application structures used for storing shared queue messages.

Up to 512 shared queues can be defined in each application structure. We have seen no significant performance effect when using a large number of queues in a single application structure.

We also have seen no significant performance effect when using multiple structures rather than fewer larger structures.

If few large application structures are used, the queues would be able to be deeper, meaning there is less likelihood of receiving an MQRC 2192 “storage medium full” message.

If using many smaller application structures, fewer queues and potentially less applications will be affected should one of the queues gets to such a high depth that an MQRC 2192 is reported.

Typically we recommend using as few CF application structures as possible, but there may be situations where it is advisable to put queues that may be deep into separate structures where an MQRC 2192 will not affect mission-critical queues.

If all the MQGETS and MQPUTS in an application are out of syncpoint, the cost of using one or more application structures remains the same.

If any MQPUTS and MQGETS are within syncpoint, a single CF application structure is recommended. For the locally driven request/reply workload using a single queue manager but with the server input queue in a different application structure to the common reply queue the unit CPU cost per request/reply increased by 6% for non-persistent messages and 12% for persistent messages. This also resulted in a decrease in throughput of 5% for non-persistent messages and 2% for persistent messages.

What size CF structures should be defined?

What values for MINSIZE, INITSIZE, and SIZE (maximum size) should be used and should ALLOWAUTOALT(YES) be specified in the CFRM (Coupling Facility Resource Manager) policy definition for IBM MQ CF structures?

- Consider making SIZE double INITSIZE.
- Consider making MINSIZE equal to INITSIZE, particularly if ALLOWAUTOALT(YES) is specified.
- It is recommended to define SIZE to be not more than double INITSIZE. The value of SIZE is used by the system to pre-allocate certain control storage in case that size is ever attained. A high SIZE to INITSIZE ratio could effectively waste a significant amount of CF storage.

If the entire CF reaches an installation-defined or defaulted-to percent full threshold as determined by structure full monitoring, the system will consider reducing the size of any structures with unused space that have been defined with ALLOWAUTOALT(YES).

For this reason we advise consideration of making MINSIZE equal to INITSIZE so that IBM MQ structures will not be made too small. This is particularly important for the CSQ_ADMIN structure which could cause failure of shared queue operations if it becomes too small (queue manager failure prior to V6).

CSQ_ADMIN

This CF structure does not contain messages and is not sensitive to the number or size of messages but it is sensitive to the number of queue managers in the QSG.

Version 7.1 updated the supplied sample member SCSQPROC(CSQ4CFRM) to specify INITSIZE of 20000KB for the example CSQ_ADMIN structure. This should be sufficiently large to allow 7 queue managers to connect to the QSG up to CFCC levels 21.

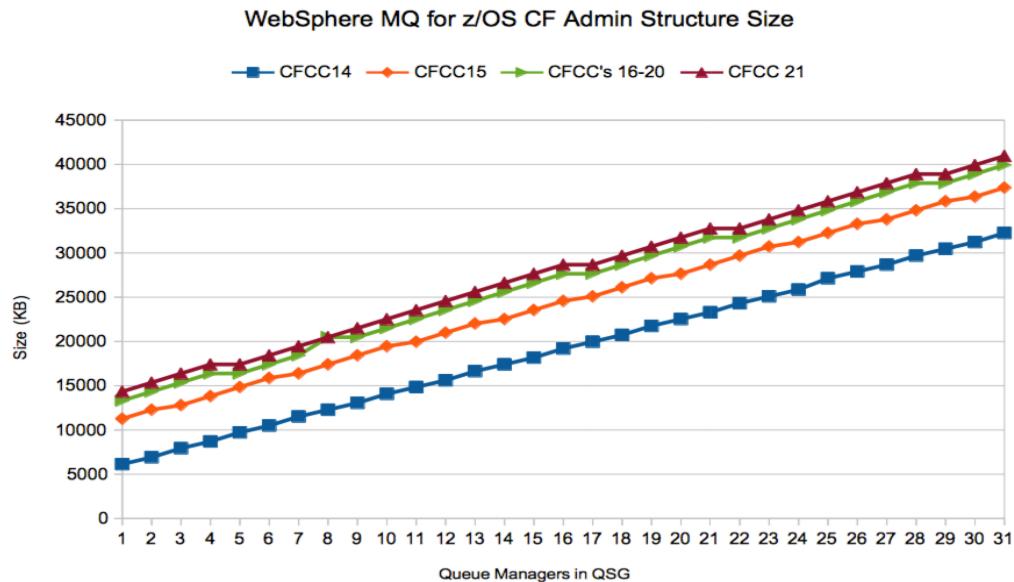
The IBM MQ command “[DIS CFSTATUS\(CSQ_ADMIN\)](#)” shows the maximum number of entries in this structure, for instance ENTSMAX(5189) on a CF at CFCC level 14. This command also shows the current number of entries used, for instance ENTSUSED(4). A queue manager in a queue sharing group is only allowed to start if there are at least 1000 entries available per started queue manager. So our example is adequate for 5 queue managers in a QSG using a CF at CFCC level 14. Each successive CF level tends to need slightly more control storage for the CF’s own purposes, so ENTSMAX is likely to decrease each time your CF level is upgraded. CFCC levels before level 12 give much larger values, for example ENTSMAX(9362) on CFCC level 10.

CSQ_ADMIN usage is affected by the number of messages in each unit of work, but only for the duration of the commit for each UOW. This only need be a concern for extremely large UOWs as the minimum size structure is enough for a UOW of about 40,000 messages. This is larger than the default maximum size UOW of 10,000, defined by MAXUMSGS.

The use of UOWs with very large numbers of messages is NOT recommended. Where large units of work are being used in conjunction with shared queues, the CSQE038E “Admin structure is full” message may be logged when there is insufficient space in the structure for the unit of work. This may be followed by the queue manager terminating with a 5C6-00C53002 abend.

How large does my admin structure need to be?

The size of the admin structure depends on the number of queue managers in your queue sharing group. The following chart shows the required size of the admin structure by number of queue managers in the QSG.



NOTE: Using a CF with CFCC level 15 uses approximately 5MB more storage than a CF with CFCC level 14.

Application structures

IBM MQ messages in shared queues occupy storage in one or more pre-defined CF list structures. We refer to these as application structures to distinguish them from the CSQ_ADMIN structure. To estimate an application structure size:

Use the IBM CFsizer available at <http://www.ibm.com/servers/eserver/zseries/cfsizer/> or the following algorithm may be used:

- Estimate typical message sizes (including all headers except the MQMD)
 - For each typical message size
 - If <= 63KB (64512 bytes) then:
 - Add the 372 bytes for implementation headers (including MQMD v1 header).
 - If using message grouping add an additional 72 bytes for the MQMDE.
 - Round up to 256 byte boundary (subject to a minimum of 1536 bytes).
 - Add 256 bytes for the CF Structure ENTRY (1 for each message)
 - Multiply by maximum number of messages.
 - Normally messages will reside in a IBM MQ application structure only long enough for the exploiting application to retrieve them. However if the exploiting application suffers an outage that prevents it from retrieving messages from the structure, the structure must be large enough to retain any messages that might be written to it, for the duration of the outage. You must therefore consider:
 1. The number of queues that map to the structure,
 2. The average put rate for each queue (i.e. the rate at which messages are written to the structure),
 3. The maximum outage duration to be tolerated.
 - Add to total for all typical message sizes
 - Add 32%¹ for CFCC level 12 and above (for other implementation considerations, this percentage can be much greater for application structures smaller than 16MB). Previous CFCC levels required the addition of 25%.
- If typical message size > 63KB (64512 bytes) then
 - For CF application structures with ALLOWAUTOALT(NO) allow about 2KB of CF storage per message larger than 63KB.
 - CF application structures with ALLOWAUTOALT(YES) will eventually have an ENTRY to ELEMENT ratio reflecting the average for all messages. This is difficult to estimate but it is usually sensible to also use this 2KB per message estimate.
However, consider the special case of all messages being larger than 63KB. The CF storage usage for shared queue messages larger than 63KB is 1 ENTRY and 2 ELEMENTS per message. This means that the actual requirement is about 1KB per message. ALLOWAUTOALT(YES) structures will eventually adjust themselves such that 1 million such messages (all larger than 63KB) would require about 1GB of CF storage.

Use this result for INITSIZE in the operating system CFRM policy definition. Consider using a larger value for SIZE in the CFRM policy definition to allow for future expansion. See “[Increasing the maximum number of messages within a structure](#)”.

¹Some of this 32% is to maintain the 1:6 entry to element ratio and some is CF overhead.

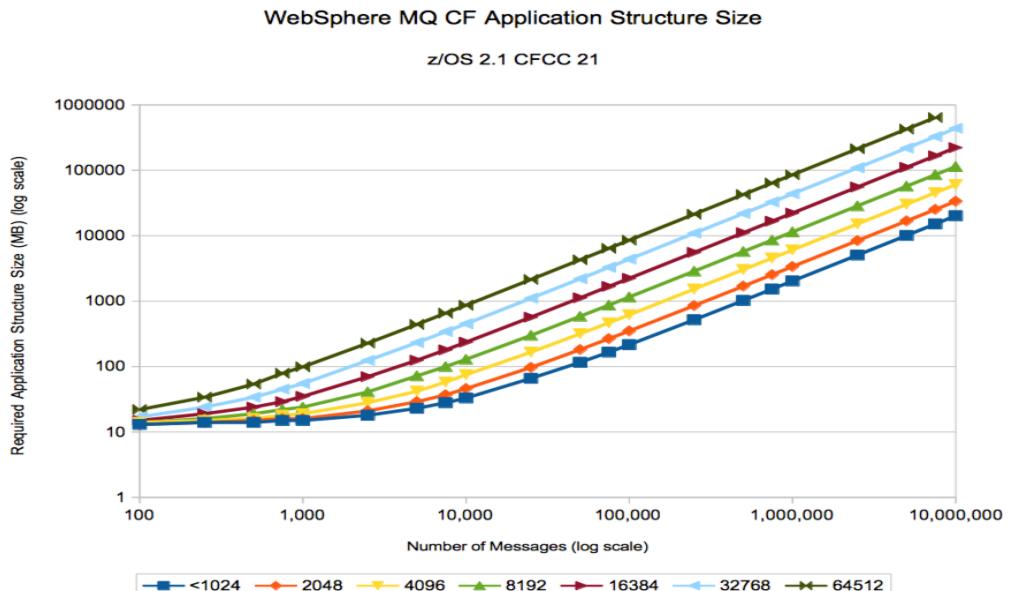
The following CFRM policy definition of an approximately 0.5GB CF list structure is typical of those used for our measurements.

```
STRUCTURE NAME(PRF2APPLICATION1)      /* PRF2 is the QSG name */
SIZE(1000000)
INITSIZE(500000)
PREFLIST(SOCF01)
```

See the IBM MQ Planning guide for details of MQ definitions.

How many messages fit in a particular CF application structure size?

To get some idea of how many messages you can get for a particular CF application structure size consult the following chart where ‘message size’ includes the user data and all the headers except the MQMD.



NOTE: The chart uses log scales. For instance the tick marks between 1000 and 10000 on the x axis are the 2000, 3000, 4000 and so on up to 9000 messages. The tick marks between 1 and 10 on the y axis are 2, 3 and so on up to 9 MB of required structure size.

For example, you can get about:

- 600 messages of 64512 bytes (63KB) in a 64MB structure,
- Or nearly 50000 16KB messages in a 1GB structure.

A CF at levels prior to CFCC level 12 will accommodate a few percent more messages than this chart, but only up to a 4GB limit.

A CF at level CFCC 15 requires the structure to be approximately 5MB larger to store an equivalent number of messages to a CF at level CFCC 14.

CF at CFCC levels 14 and later

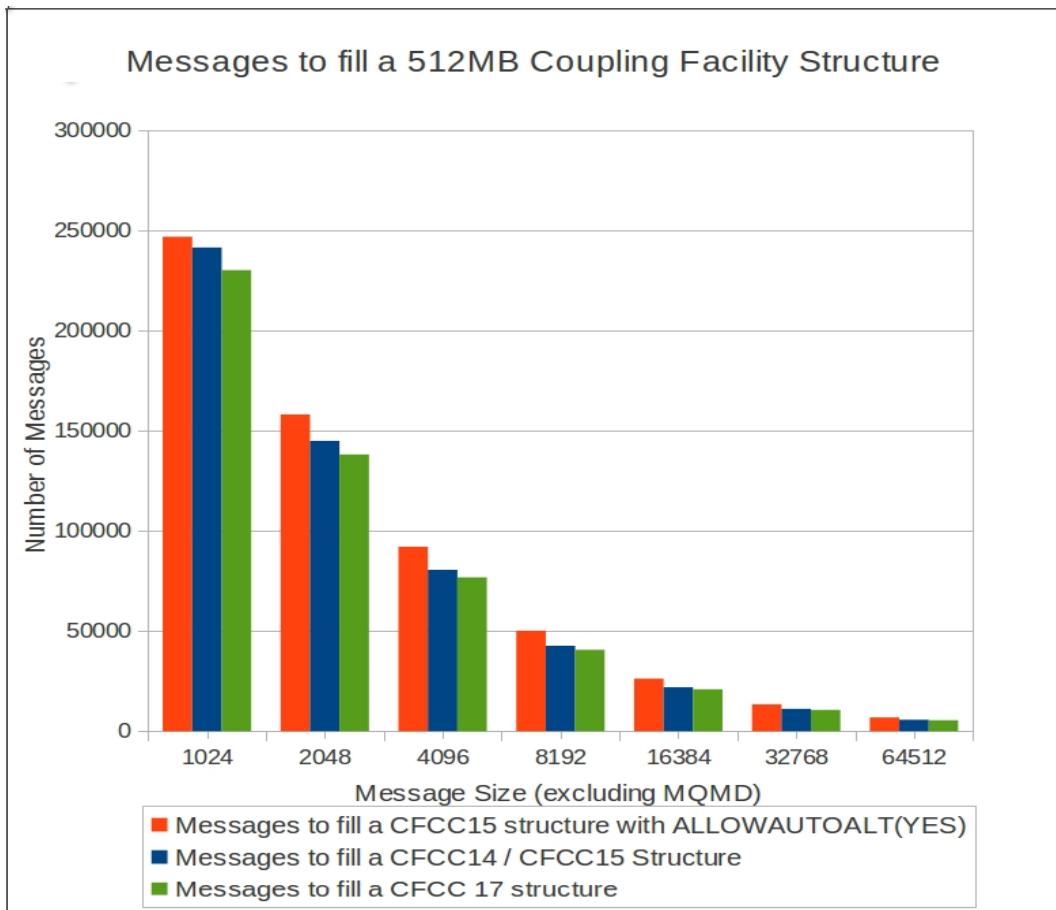
The following table gives approximate message capacity of a IBM MQ CF application structure sized

at 0.5GB, assuming it is defined in the CFRM policy as ALLOWAUTOALT(NO).

No significant differences were seen in the number of messages that could fit into a 0.5GB structure when moving to CF level 15 – once the 5MB overhead mentioned previously is taken into account.

Later CFCC release use more storage, reducing capacity somewhat e.g.:

Message size (excluding only MQMD)	Approximate messages in 0.5GB Structure	
	CF at CFCC level 14 and 15	CF at CFCC level 17-21
All message sizes <= 1164	241,000	230,000
2,048	144,800	138,000
4,096	85,000	76,700
8,192	42,500	40,600
16,384	22,000	20,900
32,768	11,100	10,600
64,512	5,700	5,500



Sizing structures at CFLEVEL(5)

CFLEVEL(5) provides the ability to increase the capacity of the CF by implementing a 3-tiered offload procedure.

Implementing tiered thresholds allows higher capacity whilst not penalising performance until the CF resource becomes constrained.

By default, the CFLEVEL(5) structure will offload messages greater than 63KB to the shared message data set.

In addition, there are 3 default thresholds:

1. Offload all messages larger than 32KB (including headers) when the structure is 70% full.
2. Offload all messages larger than 4KB (including headers) when the structure is 80% full
3. Offload all messages when the structure is 90% full.

Example: Consider a scenario where only 16KB messages are used with a 0.5GB structure.

CFLEVEL(4)

A 16KB message would require 1 entry and 66 elements.

A 0.5GB structure would support approximately 24,000 messages, with ALLOWAUTOALT=YES.

CFLEVEL(5)

16KB messages stored in the CF would still require 1 entry and 66 elements, whereas all offloaded messages use 1 entry and 2 elements.

For example, 16KB messages would not be offloaded until the structure reaches 80% full. This means that 17,101 messages are stored in their entirety in the CF. Upon reaching the 80% threshold, remaining messages are offloaded to the SMDS datasets. Provided the SMDS datasets are large enough, the CF would then be able to store a total of 158,166 messages.

Increasing the maximum number of messages within a structure

The maximum number of messages can be increased dynamically either by:

1. Increasing the size of a structure within the currently defined CFRM policy limits. This can be done by operator command or by the system for structures defined ALLOWAUTOALT(YES).
2. Using CFLEVEL(5) structures which implement tiered thresholds.
3. Changing the ENTRY to ELEMENT ratio, which can be done only by the system and only to a structure which is defined in the CFRM policy with ALLOWAUTOALT(YES)

The ELEMENT to ENTRY ratio is initially fixed by IBM MQ at 6 to 1. The system then pre-allocates ELEMENTS and ENTRIES in that ratio to fill the INITSIZE of that structure (having reserved space for its own control information including being able to cope with this structure at its maximum possible size (SIZE)).

NOTE: A structure is full if either all ENTRYs or all ELEMENTs are in use.

Every message requires an ENTRY and enough ELEMENTs to contain all message data and headers. Each ELEMENT is of size 256 bytes. Now consider the ELEMENT and ENTRY requirement for various message sizes, remembering to add the 372 bytes, that covers the implementation headers (including the MQMD v1 header), to each message.

For example,

- 5000 byte message requires 21 ELEMENTS and 1 ENTRY
- 300 byte messages require 3 ELEMENTS and 1 ENTRY
- 10 byte messages require 2 ELEMENTS and 1 ENTRY

Taking the above sizing and applying them to a simple scenario can show how we achieve the 6 to 1 ratio.

No. of Messages	Size (bytes)	ELEMENTS	ENTRY	Maintaining 6:1 ratio means:
1	5000	21	1	Unused 3 ENTRIES
1	300	3	1	Unused 3 ELEMENTS
3	10	6	3	Unused 12 ELEMENTS
Total (5)		30	5	Unused: 15 ELEMENTS 3 ENTRIES

So for the above example, we have achieved the 6 to 1 ratio, although we have lost 15 ELEMENTS and 3 ENTRIES.

If we continue to add only 5000 byte messages, we will run out of ELEMENTS long before the ENTRIES are used.

Alternatively, if we add only 10 or 300 byte messages, we will run out of ENTRIES long before we run out of ELEMENTS.

System initiated alter processing is the only way to adjust ENTRY to ELEMENT ratio for IBM MQ CF structures. It can also change the size of a CF list structure up to the maximum (SIZE) or down to the minimum defined (MINSIZE) as defined for that structure.

To see ENTRY and ELEMENT information use z/OS command ‘D XCF’, for example:

```
D XCF,STR,STRNAME=PRF2APPLICATION1.
```

Use of system initiated alter processing

This facility allows the system to alter the size of a structure (both up and down) and to change the ENTRY to ELEMENT ratio.

The following CF list structure definition is possible for application CFSTRUCT named APPLICATION1 in queue sharing group PRF2:

```
STRUCTURE NAME(PRF2APPLICATION1)
SIZE(1000000)      /* size can be increased by z/OS      */
INITSIZE(500000)    /* from 500000K to 1000000K by          */
MINSIZE(500000)    /* or decreased to 500000K by          */
ALLOWAUTOALT(YES)   /* system initiated ALTER processing */
FULLTHRESHOLD(80)
PREFLIST(SOCF01)
```

When the FULLTHRESHOLD is crossed the operating system will take steps to make adjustments to the list structure ENTRY to ELEMENT ratio to allow more messages to be held within the current size, if possible. It will also, if necessary, increase the size towards the maximum (the value of SIZE). This process is not disruptive to ongoing work provided there are sufficient processors available in the Coupling Facility. However, it can take up to several minutes after the threshold is crossed before any action is taken. This means that a structure full condition, IBM MQ return code 2192, could easily occur before any such action is taken.

For structures containing predominantly message sizes less than 908 bytes (5 * 256 - implementation headers (372)) and greater than 63KB (64512 bytes) then it is likely that considerably more messages can be accommodated in the same size structure after any such adjustment.

To reiterate, if the entire CF reaches an installation-defined or defaulted-to percent full threshold as determined by structure full monitoring, the system will consider reducing the size of any structures with unused space that have been defined with ALLOWAUTOALT(YES).

For this reason we advise consideration of making MINSIZE equal to INITSIZE so that IBM MQ structures will not be made too small. This is particularly important for the CSQ_ADMIN structure which could cause failure of shared queue operations if it becomes too small (queue manager failure prior to V6).

User initiated alter processing

The following system command is an example of how to increase the size of a structure:

```
SETXCF START,ALTER,STRNAME=PRF2APPLICATION1,SIZE=750000
```

This command increases the size of the structure but does not change the ENTRY to ELEMENT ratio within the structure. Increasing CF structure size is not noticeably disruptive to performance in our experience.

Decreasing CF structure size is not advised with CFCC levels prior to level 12 as there are circumstances where it is very disruptive to performance for a considerable time.

How often should CF structures be backed up?

Highly available parallel sysplex systems often have stringent recovery time requirements. If you use persistent messages in any particular application structure it will need to be backed up.

If backup is infrequent then recovery time could be very long and involve reading many active and archive logs back to the time of last backup. Alternatively an application structure can be recovered to empty with a “[RECOVER CFSTRUCT\(..\) TYPE\(PURGE\)](#)” command, but this does mean that any messages on the queues defined to the structure being purged will be lost.

The time to achieve a recovery is highly dependent on workload characteristics and the DASD performance for the log data sets of individual systems. However, you can probably aim to do backups at intervals greater than or equal to the desired recovery time.

CF application structure fuzzy backups are written to the log of the queue manager on which the BACKUP command is issued. The overhead to do a backup is often not significant as the number of messages in an application structure is often not large. The overhead to do a backup of 200,000 1KB persistent messages is less than 1 CPU second on a 2817-703 system.

The recovery processing time is made up of the time to:

- Restore the fuzzy backup of the CF structure, which is typically seconds rather than minutes.
- Re-apply the net CF structure changes by replaying all log data, including non-shared queue work, written since the last fuzzy backup.

The logs of each of the queue managers in the queue-sharing group are read backwards in parallel. Thus the reading of the log containing the most data since fuzzy backup will normally determine the replay time.

The data rate when reading the log backwards is typically less than the maximum write log data rate. However, it is not usual to write to any log at the maximum rate it can sustain. It will usually be possible and desirable to spread the persistent message activity and hence the log write load reasonably evenly across the queue managers in a queue sharing group. If the actual log write data rate to the busiest queue manager does not exceed the maximum data rate for reading the log backwards then the backup interval required is greater than or equal to the desired recovery time.

Backup frequency example calculation

Consider a requirement to achieve a recovery processing time of say 30 minutes, excluding any reaction to problem time. As an example, using DS8800 DASD with the queue manager doing backup and restore on a 2817-703 system running z/OS V1R13, we can restore 200,000 1KB persistent messages from a fuzzy backup on an active log in 10 seconds. To meet the recovery processing target time of 30 minutes, we have more than 29 minutes to replay the log with the most data written since the last fuzzy backup. The maximum rate at which we can read a log data set backwards is about 56MB/sec on this system, so we can read about 95GB of the longest log in 29 minutes.

The following table shows the estimated backup interval required on this example system for a range of message rates:

1KB persistent msgs/sec to longest log	1KB persistent msgs/sec to 3 evenly loaded logs	MB/sec to longest log	Backup interval in minutes (based on reading logs backwards at 56MB/Sec))
1000	3000	2.27	715
2000	6000	4.61	352
14600	43800	33.22	48
(14,600 is the maximum for this DASD with 1KB messages)			

A crude estimate for the amount of log data per message processed (put and then got) by queue managers in a QSG is message length plus 1.33KB.

Administration only queue manager

If there ever might be a lot of persistent messages or a lot of persistent message data to be backed up then the normal persistent message workload could be impacted while the log of the queue manager doing the backup is extra busy.

If this is a serious potential concern then consider defining an extra queue manager in the QSG and use it only for administration purposes such as [BACKUP CFSTRUCT\(..\)](#).

When should CF list structure duplexing be used?

CF list structure duplexing gives increased availability at a performance cost.

Any version of MQ that supports shared queues can be used with duplexed CF structures without change to either the code or the MQ definitions.

Availability within a given QSG may be summarised as follows:

SIMPLEX CF Structure definition	Action on single failure
CSQ_ADMIN V6 (or later) queue managers	<p>Queue managers stay up and rebuild this structure from their logs.</p> <p>Only serialised applications need to wait for rebuild completion.</p> <p>Rebuild only completes when every queue manager defined in the QSG has done its work. This means that if a queue manager was down at the time of failure it must be restarted before any new serialised applications can start unless the queue managers are V7.0.1 or later.</p> <p>Note: Shared channels are serialised applications.</p> <p>V7.0.1 saw the introduction of peer admin rebuild.</p>
CSQ_ADMIN V5 queue managers	<p>Entire QSG fails.</p> <p>The structure is rebuilt from logs at restart. All queue managers in the QSG need to restart to complete the rebuild.</p> <p>Only serialised applications need to wait for rebuild completion.</p>
Application structure CFLEVEL(1)	<p>ALL currently connected queue managers fail.</p> <p>On restart the structure is reallocated, all messages are lost</p>
Application structure CFLEVEL(3 or higher)	<p>No queue manager fails.</p> <p>Applications using queues in that structure fail.</p> <p>On restart persistent messages can be recovered by any queue manager in the QSG provided that any queue manager in the QSG has done a backup and all subsequent logs are available.</p> <p>Alternatively the structure can be ‘recovered’ to empty.</p>

DUPLEX CF Structure definition	Action on single failure
CSQ_ADMIN	Entire QSG remains available, z/OS recovers to duplex.
Application structure CFLEVEL(1)	ALL currently connected queue managers remain available, z/OS recovers to duplex.
Application structure CFLEVEL(3 or higher)	ALL currently connected queue managers remain available, z/OS recovers to duplex.

How does use of duplexed CF structures affect performance of MQ?

MQ operations on CF structures are typically nearly all update operations. Duplexed CF structure updates incur significant extra CF CPU and link usage. The following guidelines assume that there will be adequate total resources available. An overloaded CF is likely to cause significant performance problems for the entire sysplex.

Estimating performance for duplexed versus simplex CF structures is complex and even more than usually workload and system configuration dependent for the following reasons.

CPU costs

The CPU cost impact of duplexed CF structure compared to simplex CF structure usage depends on the link types used both between the z/OS image and the two CF's being used as well as the link between the two CF's that are being used for duplexing.

Note that one of these two CF's might have changed after a structure failure and recovery back to duplex and thus performance characteristics might also change after recovery.

Operations that update the contents of a CF structure have more impact on extra CPU cost than those that do not. MQPUTs and destructive MQGET's clearly have to update the CF structure containing the message and MQCMITs have to update the CSQ_ADMIN structure. An MQGET for browse causes no updates.

Throughput

Throughput for shared queue non-persistent messages, even when kept on duplexed CF structures, is always going to be much better than for any sort of persistent message because of the elapsed time required for DASD logging I/O necessary to provide media recovery for persistent messages.

Throughput for messages on a duplexed CF structure compared to a simplex CF structure is impacted by the type of links used between the z/OS image and the two CF's and by the type of links between the two CF's.

Any throughput impacts of duplexing CF structures are because:

- Update operations are asynchronous for duplexed CF's. They may be synchronous or asynchronous between z/OS and the CF for simplex CF structures, depending on operating system heuristic decisions.
- The operation can only complete at the speed of the slowest link.
- The second CF may be physically much more distant (possibly many kilometres and even light takes time to travel). 10KM distance will add something of the order of 200 - 250 microseconds to the service time for each request.

CF Utilization (CF CPU)

The CF utilization cost will increase significantly for MQ update operations when using duplex rather than simplex CF list structures.

- Each of the duplexed CF's must process the operation
- Plus there is synchronization between the CF's.

The CF utilization for MQ update operations on the CF of the primary copy structure will approximately double. The secondary copy CF utilization will be nearly as much as the primary.

Environment used for comparing Simplex versus Duplex CF structures

1 LPAR on a 2084 with 3 dedicated processors, rated as a 2084-303, with ICP and CFP links to local coupling facility. ICP link (fastest) will be used when available.

Coupling facility has 3 engines available.

Physically the duplexed structures are located locally but only CFP (ISC-3) links between the 2 coupling facilities.

Multiple Queue Sharing Groups defined:

- One with duplexed CSQ_ADMIN structure and 3 application structures of which one is duplexed.
- All other QSGs have simplexed CSQ_ADMIN structure and 3 application structures of which one is duplexed.

Locally driven request / reply workload with multiple requester applications putting to a common input queue and getting a reply message by CORRELID from a separate common indexed queue. Multiple server applications getting from the common input queue and putting to the reply-to queue.

Duplexing the CSQ_ADMIN structure

From observations on our system when running our locally driven request / reply workload we have derived the following general guidance.

Note: The test system has a multiple links from the LPAR to the primary CF, including a fast ICP link which will be used when available, and a slow link from the primary CF to the secondary (duplexed) CF.

- CPU cost between 0% and 30% greater.
- For non-persistent messages processed in-syncpoint, throughput decreases by 30% for 1KB and 20% for 32KB messages.
- For persistent messages processed in-syncpoint, throughput decreases by 25% for 1KB and 12% for 32KB messages.
- The contribution of CSQ_ADMIN structure usage to CF utilization is usually much less than that for the application structures. Duplexing the CSQ_ADMIN structure might typically increase the MQ caused load by 10% for 63KB non-persistent messages to 33% for 1KB non-persistent messages.
- The use of messages contained in more than one application structure within a unit of work increases the activity to the CSQ_ADMIN structure and so would further increase CPU and CF utilization and decrease throughput.

Using a slower CFP link from the LPAR to the primary CF and another CFP link from the primary CF to the duplexed CF:

- CPU cost between 3 and 8% greater
- For non-persistent messages processed in-syncpoint, throughput decreases by 18% for messages between 1 and 63KB.

When using the faster ICP link between the LPAR and the primary CF with a slower CFP link from the primary CF to the secondary CF, the additional cost of duplexing the admin structure is significantly more than when running with a CFP link from the LPAR to the CF. Despite this, the faster ICP link does allow up to 40% more throughput for 1 to 63KB non-persistent messages that are processed in-syncpoint.

Duplexing an application structure

It really only makes sense to duplex an application structure if the CSQ_ADMIN structure is also duplexed. From our observations on our system with our locally driven request /reply workload we have derived the following general guidance for duplexing of both CSQ_ADMIN and the application structure.

NOTE: The test system has a multiple links from the LPAR to the primary CF, including a fast ICP link which will be used when available, and a slow link from the primary CF to the secondary (duplexed) CF.

- CPU cost about 15% greater for 1KB persistent messages and 30% greater for 1KB non-persistent messages.
- CPU cost about 12% greater for 32KB persistent messages and 25% greater for 32KB non-persistent messages.
- Throughput decrease by 40% for 1KB non-persistent messages and 50% for 10KB non-persistent messages. For persistent messages throughput decrease is negligible for 1KB messages and rises to less than 10% for 32KB messages. The use of messages contained in more than one application structure within a unit of work increases the activity to the CSQ_ADMIN structure and so would further decrease throughput.
- The contribution of MQ CF structure usage to CF utilization will double for the primary structures. The secondary structures will use almost as much as the primary.

Non persistent shared queue message availability

Non-persistent messages are not logged whether in private or shared queues. Therefore they cannot be recovered if lost. Nevertheless, shared queue non-persistent messages have much greater availability than private queue non-persistent messages.

Private queue non-persistent messages are lost when the queue manager fails or shuts down normally. Even with simplex CF structure usage shared queue non-persistent messages are not easily lost. They are only lost if the CF application structure containing them fails or is deleted by the operator. In particular, they are NOT lost when any or even all queue managers in a queue sharing group fail or shut down normally (except failure caused by loss of that application structure).

Users may consider using non persistent shared queue messages, with all the advantages of pull workload balancing which come with use of shared queue, where they might previously have required persistent messages in a non-shared queue environment. In this case there is generally a CPU cost saving and potentially a significant increase in throughput compared to use of non-shared queue persistent messages.

Existing users of private queue persistent messages moving to shared queue non-persistent messages on CF structures may see a CPU cost saving and potentially a significant increase in throughput even when using duplexed CF structures.

Coupling Facility

What is the impact of having insufficient CPU in the Coupling Facility?

As the coupling facility becomes more utilized, the system will convert synchronous requests to asynchronous requests. The system has heuristic algorithms which decide that the system will be more efficient if it issues an asynchronous request with the cost of a re-dispatch, rather than have the processor wait for a synchronous request to complete. With the asynchronous request, the processor can process other work.

With a highly utilized coupling facility, a small increase in utilization can result in significant increase in coupling facility response time when the CF requests are changed from synchronous to asynchronous.

By example:

- When the CF was 20% utilized, the majority of the CF requests were synchronous taking 4.4 microseconds.
- When the CF was 70% utilized, the majority of the CF requests were synchronous taking approximately 9.9 microseconds, but those asynchronous requests were taking 600 microseconds.

When do I need to add more engines to my Coupling Facility?

On a coupling facility with 1 engine, it is advised that when the %busy value exceeds 30% for any period of time, an additional engine should be added. On a coupling facility with multiple engines, it is advised that when the %busy value (as can be seen from an RMF III “CF Activity” report) exceeds 60%, an additional engine should be added.

What type of engine should be used in my Coupling Facility?

The CF can use general CP's that can also be used by the operating system LPAR or an ICF, which can only run CFCC. For performance reasons, the ICF engines do not share L3 and L4 caches with z/OS processors.

IBM recommends that *dedicated engines should always be used for a CF whose response times are critical.*

If dedicated processors are not available, review “[Use of Shared Engines for Coupling Facilities – Implementation and Impact](#)” for information on the use of the dynamic dispatch “DYNDISP” configuration option.

CF Level 19 - Thin Interrupts

With the introduction of CFCC level 19, the options for sharing CF processors increased such that the Dynamic CF dispatching (DYNDISP) option now supports ON, OFF and THIN.

The performance of THIN interrupts is discussed in detail in the white paper “[Coupling Thin Interrupts and CF Performance in Shared Processor Environments](#)”.

Why do I see many re-drives in the statistics report?

What is a re-drive?

The Coupling Facility manager data records (QUEST) hold data about re-drives in 2 fields.

1. QESTRSEC - number of IXLLSTE redrives
2. QESTRMEC - number of IXLLSTM redrives

When IBM MQ attempts to get data from the coupling facility but has not specified a large enough buffer for the requested data, XCF returns the [IXLRSNCODEBADBUFSIZE](#) return code. As a result, IBM MQ redrives the request to get the data using a larger buffer.

Why do I see many re-drives in the statistics report?

For performance reasons, it is better to use a buffer that is close to the size of the data (including headers) to be gotten - as a result, the initial buffer size used by MQ is 4KB and this will be increased or decreased as necessary.

IBM MQ uses a range of buffer sizes i.e. 256 bytes, 512 bytes, 1024 bytes, 2048 bytes and then the size of the buffers increase in 4KB blocks up to 63KB.

IBM MQ stores the size of the last message and uses this size for the buffer on the next get, as typically it is expected that all the messages on the queue are the same size. If the message size increases above the size of the current buffer, a redrive will occur. For example, consider a shared queue has 5 messages of varying size (including MQ headers).

Message	Size of Message (KB)	
1	5	Redrive occurs
2	6	
3	8	
4	10	Redrive occurs
5	1	

In this example, you would see 2 re-drives – associated with message 1 (as it is larger than the initial 4KB buffer size) and message 4 (as it is larger than the next boundary (8KB)).

In version 6.0.0, MQ may resize the buffer immediately if the buffer is deemed too large, so consider the following example:

Message	Size of Message (KB)	
1	1	
2	0.5	
3	1	Redrive occurs
4	4	Redrive occurs

NOTE:

- Message 1 does not require a re-drive but the 4KB initial buffer was inefficient, so the buffer is resized to 1KB for subsequent attempts.
- Message 2 can be gotten into a 1KB buffer, so is also successful without a re-drive, but the buffer is inefficient, so the buffer is resized to 512 bytes for subsequent attempts.

- Message 3 does not fit into a 512 byte buffer, so we get a re-drive and the buffer is set to 1KB for subsequent attempts.
- Message 4 does not fit into the 1KB buffer, so again there is a re-drive and the buffer is set to 4KB.

WebSphere MQ version 7.0 changed the behaviour of the sizing down process – it only sizes the buffer down if the buffer was too large for 10 consecutive messages. In the previous example, there would have been no redrives.

Effect of re-drives on performance

If there are a high number of re-drives, it would indicate that the messages being retrieved by MQGET are of varying size – it may be that the messages are not varying in size by much but they are near to one of the boundaries – e.g. some messages are 4080 bytes and some are 4100 bytes.

When there are a large number of re-drives, the cost per transaction may be higher and the transaction rate lower than when the messages do not cause re-drives.

To show how the cost of re-drives can affect the cost and rate of transactions, the following scenario was run:

- A version 6.0 queue manager in a queue sharing group is started
- 5 requester tasks each put non-persistent messages to a single shared queue and then wait for a reply message on a shared reply-to queue that is indexed by MSGID. Each requester will then repeat until told to stop.
- 4 server tasks that get messages from the shared input queue and MQPUT a reply message to the shared reply-to queue
- Measurements were run on a single LPAR using z/OS 1.9 with 3 dedicated processors on a z10 EC64.
- Message sizes specified exclude headers

There are 3 test cases measured:

1. All messages are 2KB
2. All messages are 4KB
3. 3 in 5 messages are 2KB, 2 in 5 messages are 4KB

Message Size	Transaction Rate / Second	Cost / Transaction (microseconds)	Single Retries on Application Structure
2KB	9758	291	0
4KB	9405	302	1
Mixed	9117	313	457,825

As can be clearly seen from the above measurements, using mixed size messages that cross re-drive boundaries on the queue results in a high re-drive count.

It also shows that the transaction rate and cost per transaction is worse than when using larger fixed sizes messages.

It should be noted that if these measurements were repeated using WebSphere MQ v7.0 or later, it is likely there would be minimal re-drives.

Batch delete of messages with small structures - CFLEVEL(4) and lower

When shared queue messages are gotten destructively, the queue manager saves the pointer (PLEID) to the storage used to hold the message in the coupling facility in a batch delete table. When this table is full, MQ initiates an SRB to request that the data pointed to in the coupling facility is deleted.

There is a batch delete table held in each queue manager for each structure that the queue manager is attached to. Each table can store 341 entries before the batch delete process will be initiated.

This means that when putting and getting messages to an application structure, there may be up to 340 messages in the structure per queue manager in the QSG that are waiting to be deleted.

If the messages are 63KB, this means that there could be 340 messages – or 21.25MB of messages waiting to be deleted – per queue manager.

This means that if there were 30 queue managers in a QSG and messages of 63KB were being used, there could potentially be (30 x 21.25MB) 637.5MB of messages waiting to be deleted.

If the application structure is not large enough to hold these “dead” messages as well as any “live” messages, an application putting to a queue on the structure may get an MQRC 2192 “Storage Medium Full”.

Constraint relief may be gained by:

- Enabling ALLOWAUTOALT(YES) – This may change the ratio of elements to entries which may give an increased capacity.
- Increasing the size of the structure
- Using CFSTRUCT’s at CFLEVEL(5)

Shared Message Data Sets - CFLEVEL(5)

WebSphere MQ for z/OS version 7.1.0 introduced CFLEVEL(5) to store large messages in shared message data sets (SMDS), instead of DB2 for messages larger than 63KB.

This can offer a reduction in management costs for storing large shared queue messages as well as improving the throughput rates achievable.

In addition, a 3-tiered message size offload threshold is introduced to increase the capacity of the CF.

For detailed performance guidance on the use of CFLEVEL(5), please refer to “[MP1H: WebSphere MQ for z/OS V7.1.0 Performance Report](#)”.

DB2

IBM MQ uses DB2 with shared queues for a number of reasons, including storing information about queue managers configuration, group objects, channel status and large (greater than 63KB) messages.

The DB2 LOB tablespace supplied definitions specify 32KB buffer pool usage. The DB2 table space requirement is therefore of order:

1. Number of 32KB’s required for typical message (including all headers) * maximum number of messages

- For example, ten thousand shared queue messages of size typically 100KB would require 4 such 32KB's per message and therefore of order 1280MB LOB table space.

There is no queue manager requirement for a particular LOB table space buffer pool size. Other sizes may be used although no performance advantage has been observed using different sizes.

The DB2 supplied definitions specify NUMPARTS 4 to improve maximum throughput. This number can be changed to suit particular workload requirements. We did not find significant benefit from using a greater number of partitions. Each message is stored within a single partition. The partitioning is pseudo-random based on the time the message is MQPUT.

If the partition to which a message is to be MQPUT is full then a 2192 (media full) reason code will be returned even if there is still space in other partitions. Thus it is sensible to add another 10% to LOB tablespace requirements to allow for any uneven usage of partitions. For example, the above calculation of 1280MB split across 4 partitions could sensibly be spread across four partitions each of $(1280/4 + 10\%)$ 352MB.

Is DB2 tuning important?

Yes, because DB2 is used as a shared repository for both definitional data and shared channel status information. In particular BUFFERPOOL and GROUPBUFFERPOOL sizes need to be sufficiently large to avoid unnecessary I/O to DB2 data and indexes at such times as queue open and close and channel start and stop.

The DB2 RUNSTATS utility should be run after significant QSGDISP(SHARED) or QSGDISP(GROUP) definitional activity, for instance, when first moving into production. The plans should then be re-bound using SCSQPROC(CSQ45BPL). This will enable DB2 to optimize the SQL calls made on it by the queue manager.

- For shared queue messages > 63KB
- Isolate the IBM MQ used DB2 LOB table space into a 32K buffer pool of its own.
- A group buffer pool definition corresponding to the chosen buffer pool will need to be defined.
We used a group buffer pool CF structure definition with POLICY SIZE: 10240 K.

Why does IBM MQ produce more DB2 rollbacks than I expect?

When running a DB2 log print you may see an unexpectedly high number of rollbacks for the IBM MQ plans that are prefixed CSQ5. The reason for these unexpected rollbacks is that the occurrence of any non-zero return code (including +100 – “not found”) at the end of the DB2 activity will result in a rollback being issued. In particular there may be a high number of CSQ5L prefixed plans that have rollbacks associated with them. The CSQ5L prefixed plan is used when IBM MQ periodically checks for new objects being created.

Shared queue messages > 63KB

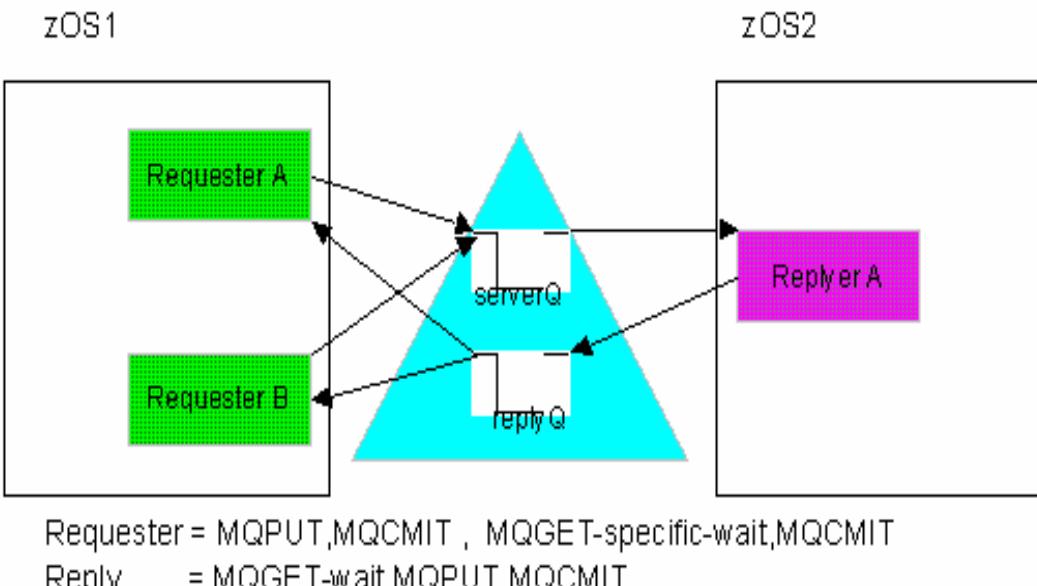
Throughput and response time for shared queue messages <=63KB has been and remains most dependent on:

- For persistent messages, I/O rate and total data rate achievable by individual IBM MQ logs in the queue sharing group for all persistent messages processed by individual queue managers.
- For all messages, CF link type and CF power

Throughput and response time for all shared queue messages > 63KB is additionally dependent on:

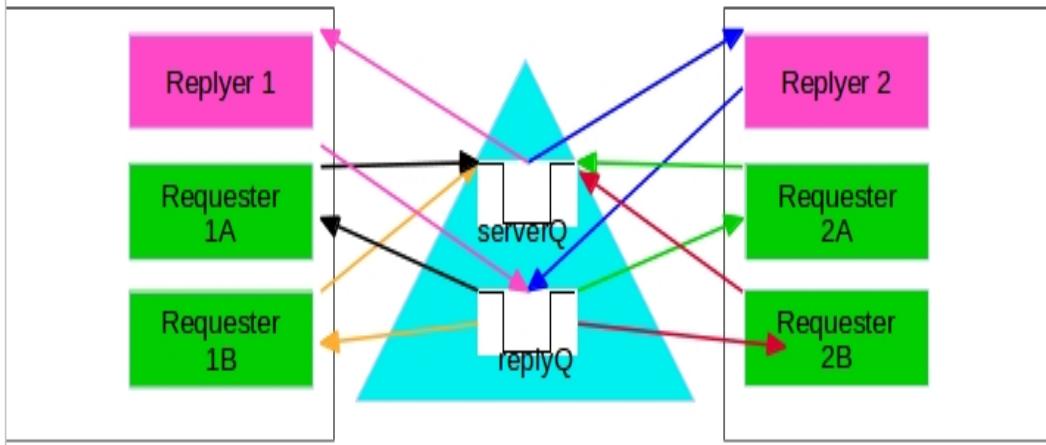
- I/O rate and total data rate achievable by DB2 LOB table DASD.
- I/O rate and total data rate achievable by individual DB2 logs across the data sharing group.
- The percentage of cross DB2 data sharing, which also impacts CPU costs.
- Persistent messages are logged to the IBM MQ log. DB2 LOB table control information is logged to the DB2 log for persistent and non persistent messages. LOB data (the message) is not logged by DB2.
- The queue manager issues all DB2 calls on behalf of any application using >63KB shared queue messages. For virtual storage reasons the messages are segmented, if necessary, into multiple 512KB LOB table entries containing 511KB of message data. This has the following effects
 - CPU costs for shared queue messages > 63KB are mostly incurred by the queue manager and DB2 address spaces rather than the application.
 - Maximum throughput and response time can be impacted across 511KB boundaries
 - CPU costs are increased across 511KB boundaries

100% data sharing is most expensive, that is, where the putter and getter are always in different z/OS's. An example of 100% data sharing is where a shared queue has replaced a channel between queue managers.



Where there is effectively a set of cloned systems in a sysplex then data sharing is reduced. For example, consider a set of IBM MQ applications which do all the puts and gets to a set of shared queues. If this set of applications runs on each of 2 queue managers that are connected to separate DB2's in a data-sharing group then there is theoretically 50% data sharing. That is there is a 50% chance that the getter of any particular message will be using a different DB2 to the putter. (66.6% for 3 clones)

Example 50% datasharing case - 2 cloned zOSs



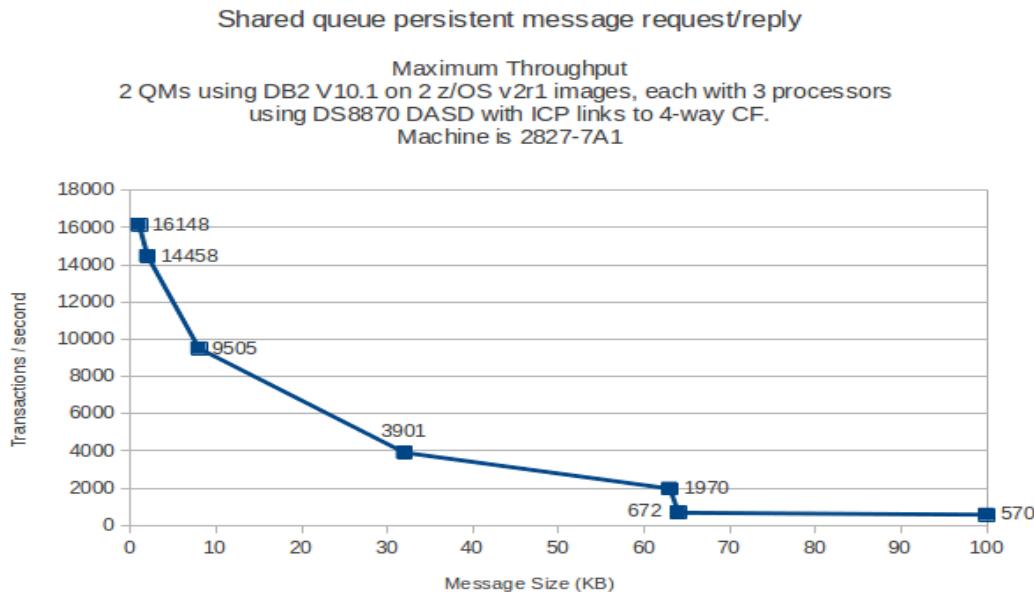
There is also the case where no actual data sharing occurs. This could be because the shared queues requiring messages > 63KB are used only by queue manager(s) each connected to the same DB2. This is most likely to occur in test system setups. DB2 only starts using data sharing locks and group buffers on first LOB table usage by a second DB2.

Finally, out-of-syncpoint non-persistent messages can be MQPUT directly to a waiting out-of-syncpoint MQGETter for shared queues where the waiting getter is connected to the same queue manager as the putter. When this happens there is no interaction with the CF application structure or DB2. Thus the response time and CPU cost is very much reduced when this happens.

NPM SPEED(FAST) receiving channels use out-of-syncpoint MQPUTs for non persistent messages. Thus applications using out-of-syncpoint MQGET on shared queues fed by such channels can benefit. NPM SPEED(FAST) sending channels use MQGET with sync-if-persistent. Thus such channels fed by applications using out-of-syncpoint MQPUTs of non-persistent messages can benefit.

Shared queue persistent message throughput after 63KB transition

The following chart shows the significant discontinuity in throughput at the 63KB transition point. In particular shared queue persistent message throughput drops from 1970 messages/second to 672 messages/second as message size passes 63KB.



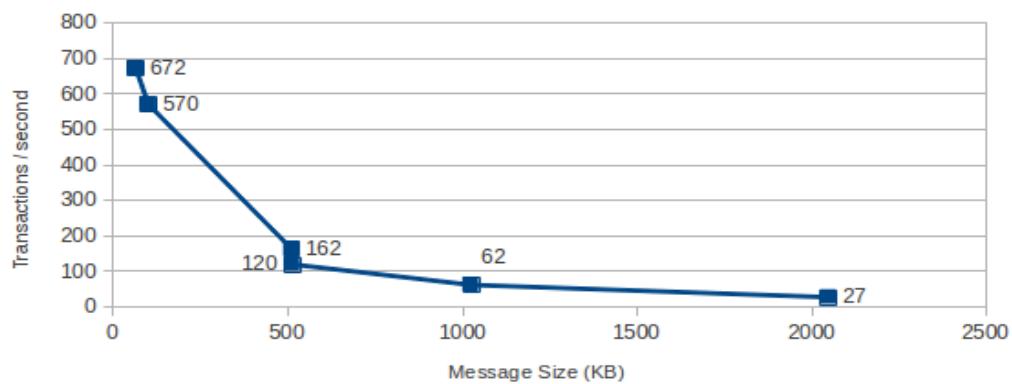
This shared queue scenario is an example of 50% data sharing. There are 2 DB2's with a cloned set of applications using each DB2.

The queue manager issues all DB2 calls on behalf of any application using >63KB shared queue messages. For virtual storage reasons the messages are segmented, if necessary, into multiple 512KB LOB table entries containing 511KB of message data. This has the following effects:

- CPU costs for shared queue messages > 63KB are mostly incurred by the queue manager and DB2 address spaces rather than the application.
- CPU costs are increased across 511KB boundaries – as can be seen in tables following.
- As message size doubles, the transaction rate typically halves.

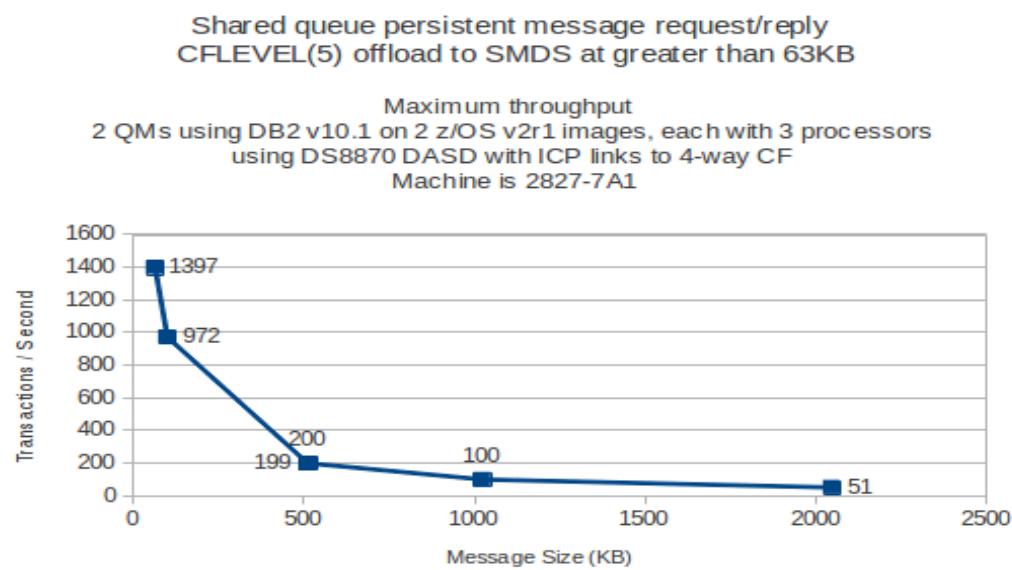
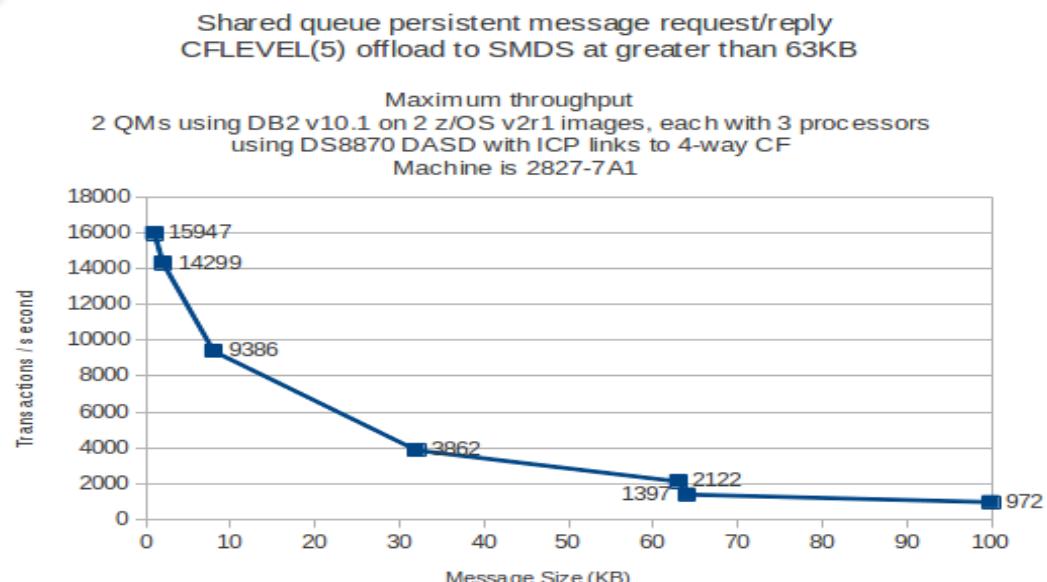
Shared queue persistent message request/reply

Maximum Throughput,
2 QMs using DB2 v10.1 on 2 z/OS v2r1 images, each with 3 processors
using DS8870 DASD with ICP links to 4-way CF
Machine is 2827-7A1



For comparison purposes, the preceding measurements have been repeated using CFLEVEL(5) using shared message data sets to store the message payload with the default tiering options used. This means that in a coupling facility structure that is not running close to capacity, messages of 63KB or less are stored in the coupling facility.

The following chart shows how using CFLEVEL(5) in conjunction with offloading to shared message data sets with the default offload tiers, the transition from storing the message in the CF to storing the message in the SMDS is significantly smoother than storing the message payload in DB2.



NOTE: As the messages get larger, the benefits of offloading persistent shared queue messages are not obvious from the transaction rate, as the primary factor restricting transaction rate is the queue managers log rate.

Shared queue persistent message request/reply CPU costs

The preceding throughput measurements show the following CPU cost per message (put and gotten) for estimating purposes.

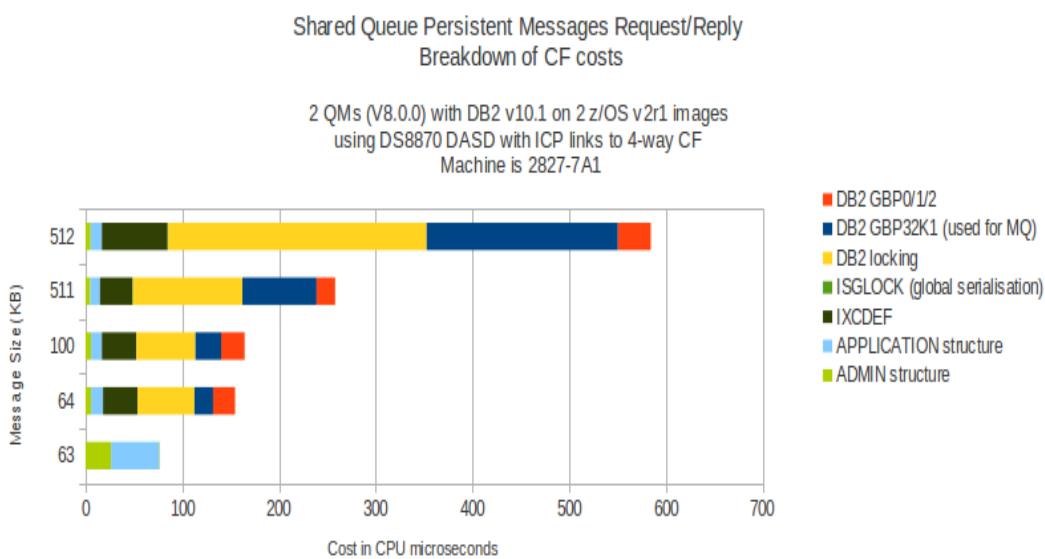
2817-7A1 (partitioned as two 3-way LPARs) CPUmillisecs/msg		
Message size (Bytes)	CPUmillisecs/msg using CFLEVEL(4)	CPU milliseconds / message using CFLEVEL(5) offload to SMDS
2048	0.12	0.12
8192	0.13	0.13
32768	0.19	0.19
64512	0.28	0.27
65536	1.45	0.26
102400	1.47	0.32
523264	3.24	1.16
524000	5.55	1.16
1048576	10.6	2.49

Shared queue persistent message request/reply CF costs

The following table shows the CF CPU cost per message as obtained in the persistent messages in a shared queue environment measurements described previously. The costs are provided for estimating purposes.

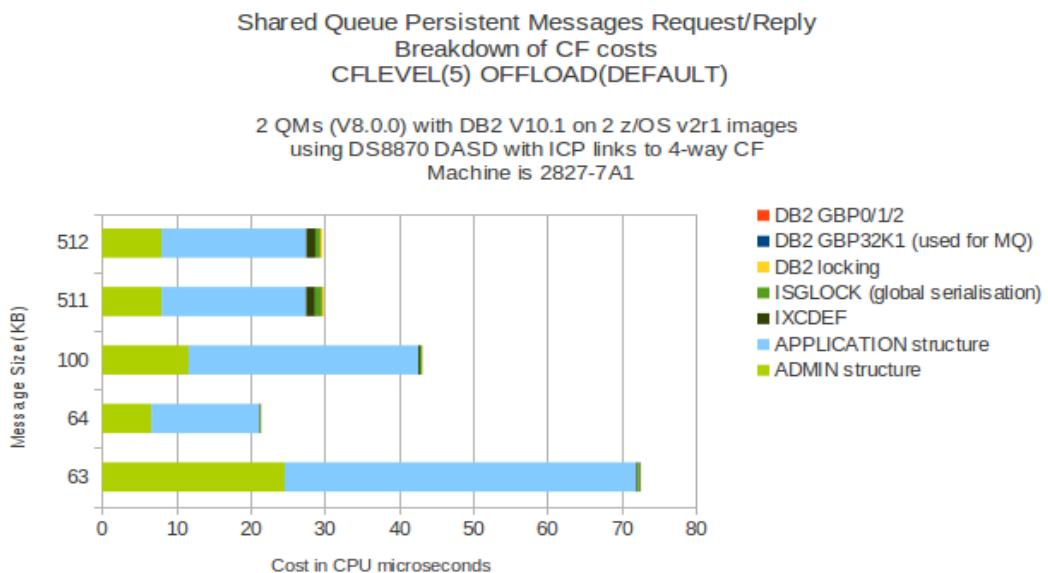
2817-779 (partitioned as 3-way internal CF) CFmillisecs/msg		
Message size	CF CPUmilliseconds / message using CFLEVEL(4)	CPU milliseconds / message using CFLEVEL(5) offload to SMDS
2048	0.36	0.36
8192	0.41	0.41
32768	0.53	0.53
64512	0.76	0.73
65536	1.54	0.21
102400	1.64	0.43
523264	2.58	0.3
524000	5.85	0.3
1048576	14.23	0.6

The following chart shows the breakdown of cost by component for a variety of shared message sizes.



NOTE: Messages of size less than 63KB see costs incurred by the primarily by the Admin structure and also the application structure. As the message size exceeds 63KB, the messages are stored on DB2 tables – resulting in the DB2 lock structures being used more as well as the IXCDEF coupling facility structure that is used to ensure the separate MVS' are synchronized. As the messages reach the size of a DB2 BLOB, the usage of the DB2 buffer pool created specifically for MQ messages increases too.

For comparison purposes, the following chart shows the breakdown of the cost by component for a variety of shared message sizes when offloading messages larger than 63KB to shared message data sets.



NOTE: Using shared message data sets to store messages larger than 63KB is significantly less expensive in CF costs than using DB2 as there is less requirement on the DB2 structures including locking.

Storage Class Memory (SCM)

Storage Class Memory (SCM), also known as CF Flash, is a new feature added on the zEC12 and zBC12 machines, which can be used to provide a high total storage capacity for a CF structure without needing to define excessively large amount of real memory.

Example uses of SCM on z/OS:

- Improved paging performance
- Improved dump capture times
- Pageable 1MB memory objects
- Coupling facility (CF) list structures used by MQ shared queues.

Using SCM with IBM MQ

The use of MQ with SCM is discussed in detail in redbook “**IBM MQ V8 Features and Enhancements**” available “<http://www.redbooks.ibm.com/abstracts/sg248218.html>”, which also suggests possible use cases.

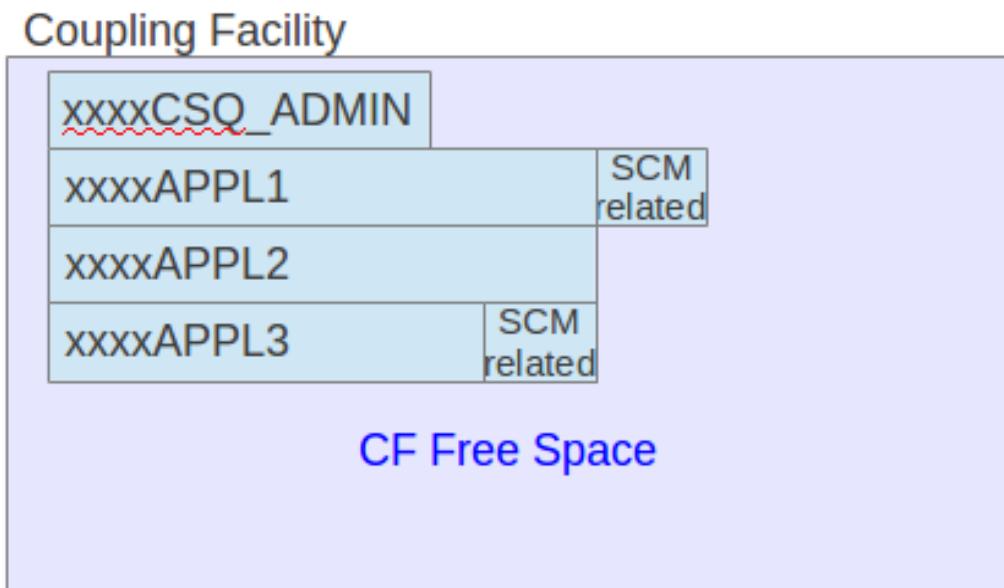
It is suggested that the CF Sizing tool available at “www.ibm.com/systems/z/cfsizer” is used to determine the sizing and impact of SCM on new or existing structures.

Impact of SCM on Coupling Facility capacity

Configuring a structure to be able to use SCM does have an impact on the capacity of the Coupling Facility and existing structure.

- Structure control storage. When a structure is configured to use SCM, the amount of control storage used by that structure increases. This means that a list structure configured with SCM will be able to contain fewer entries and elements than a structure of the same size without SCM configured.
- Augmented storage.
 - Fixed. This storage is allocated when a structure is configured with SCM. This is a small amount and will be allocated even if the structure never uses any SCM.
 - Dynamic. As data from the structure is stored in SCM, augmented space will be allocated from the free real storage in the CF.

Consider the following diagram of a Coupling Facility that has been configured for use by IBM MQ:
In the example, there are 3 application structures defined.



Notes:

- APPL1 and APPL3 have SCM available for additional capacity, and this additional structure control space is denoted by “SCM related”.
- APPL1 and APPL2 have been defined so that they have the same number of entries and elements. This has been achieved by making APPL1 larger to contain the addition SCM related storage.
- APPL2 and APPL3 are the same size but APPL3 has less entries and elements due to SCM related allocations, therefore less capacity in real storage.
- As the SCM storage is used, additional augmented space will be allocated from the CF free space.

How much SCM is available?

The amount of SCM available is ultimately limited by:

- The capacity of CF Flash.
- How much SCM is allocated to the CF.
- How much is actually being used by other structures in the CF.
- How much free space there is in your coupling facility as some may be used for dynamic augmented space. A lack of free space in the CF can limit the amount of space used in SCM.

How do I know I am using SCM and how much?

Using the D XCF,STR,STRNAME=<...> command, which will give output like:

```
..  
SCMMAXSIZE      : 1048576 M  
..  
STORAGE CONFIGURATION          ALLOCATED        MAXIMUM      %  
ACTUAL SIZE:                  4114 M          4114 M    100  
AUGMENTED SPACE:              3 M            77455 M     0
```

This shows that the structure can use up to 1TB of storage and with no data having been written to SCM, there was 3MB of augmented space used from the CF's available free space.

It has been calculated that to use the entire 1TB of available SCM space, 77,455MB of augmented space would be required – therefore the CF needs to have sufficient capacity available.

ALLOWAUTOALT(YES) usage with SCM

When ALLOWAUTOALT(YES) is defined, the threshold for altering the ratios of entries to elements is specified using the FULLTHRESHOLD keyword and is typically reached (80% full as configured by the FULLTHRESHOLD keyword) before the SCM pre-staging algorithm is invoked (90% full).

The altering of the entry to element ratio by the ALLOWAUTOALT process can take time and if the structure usage continues to increase whilst the process is continuing, the SCM pre-staging algorithm may start.

Once the SCM pre-staging algorithm starts, the ALLOWAUTOALT entry to element ratio is frozen until the structure no longer has data residing in SCM. If the auto-altering has not completed or even started, the entry to element ratio used by SCM might be inefficient.

Useful guidelines:

- Never over-commit SCM. If you do, then the applications that are relying on it will not get the behaviour that they expect. For example, MQ applications using shared queues might get unexpected MQRC_STORAGE_MEDIUM_FULL reason codes.
- Be aware of the augmented space usage as this can affect the CF usage. If your CF is constrained for space, you may run out of free space before either the structure or SCM is constrained. This will still result in MQRC_STORAGE_MEDIUM_FULL reason codes.

Impact of CF Flash on Application performance

The following chart shows the maximum rate in MB per second that we were able to write to SCM and read from SCM for a range of message sizes.

These measurements involved accessing messages in priority order using separate putting and getting applications.

Message Size	Write to SCM	Read from SCM
2KB	190 MB/sec	137 MB/sec
8KB	400 MB/sec	266 MB/sec
16KB	480 MB/sec	414 MB/sec
62KB	490 MB/sec (seeing 39% of requests delayed)	450 MB/sec

When the workload was contained in CF real storage, the MQPUT and MQGET rates were up to 10% higher on a 4-way CF with sufficient paths available between the MVS and CF LPARs, as access to CF real storage is faster.

When the MQPUT and MQGET rate is below the peak rates shown in the table, pre-staging and pre-fetching is typically asynchronous and as a result, no significant difference in performance was observed whether messages were stored in CF only or CF and SCM.

Non-Sequential gets from deep shared queue

SCM uses the KEYPRIORITY1 algorithm with MQ shared queues to determine the order that messages are written to SCM (pre-staging) and the order messages are migrated back into the CF (pre-fetching).

Both the pre-staging and pre-fetching are typically performed asynchronously to reduce the chance of the application being blocked whilst synchronous I/O to/from SCM occurs.

Pre-fetching using the KEYPRIORITY1 algorithm works on the assumption that messages will be gotten in MQ message priority order. Multiple messages are pre-fetched, the number dependent upon the message size.

When processing messages out of priority order, the pre-staging and pre-fetching function controlled by the KEYPRIORITY1 algorithm is unable to accurately predict which messages can be pre-staged and which messages need to be pre-fetched next. This can result in significantly more expensive MQPUTs and MQGETs.

Consider the following scenarios:

- There are a number of 2KB messages on a shared queue such that all of the messages remain in CF real storage. These messages are randomly got and put by a single application
- There are a number of 2KB messages on a shared queue that has been configured with SCM such that the majority of messages are stored on SCM. These messages are randomly got and put by a single application.

	MQPUT		MQGET	
	Elapsed (microseconds)	CPU (microseconds)	Elapsed (microseconds)	CPU (microseconds)
All messages in CF real	8	8	19	19
Most messages in CF Flash (SCM)	1700	25	3600	80

In the scenario where messages are randomly got and put primarily from SCM, the difference between the elapsed and CPU time is due to additional time spent processing the migration of the messages to and from SCM. In these measurements, the CF cost per message is approximately the difference between the elapsed time minus the CPU time.

This means that this type of workload would result in a significantly lower throughput rate as well as an increase in cost to both the MVS and CF LPARs.

RMF data

The z/OS RMF Coupling Facility report, requested by “SYSRPTS(CF)” has been updated in z/OS v2r1 to include an “SCM Structure Summary” report. An example of this is shown below:

SCM STRUCTURE SUMMARY															
TYPE	STRUCTURE NAME	SCM SPACE		AUGMENTED		LST ENTRY		LST ELEM		--- SCM READ ---		--- SCM WRITE ---		SCM AUX	DELAYED
		MAX/ ALG	%USED	EST.MAX/ %USED	EST.MAX/ %USED	CUR	CUR	X'FERRED	STD.DEV	CNT/BYTE	AVG ST/	CNT/BYTE	AVG ST/	ENABLED	FAULTS
LIST	PRF1APPLICATION1	KP1	1024G	77455M	613417K	3681M	32339	1583.3	32336	1396.7	0	353138			
				1.0	0.6	4034K	40343K	33910M	1171.2	33907M	839.9	0.0	498		

This example shows:

- List structure PRF1APPLICATION1 is defined with up to 1TB of SCM storage using algorithm KEY_PRIORITY1. This algorithm determines which messages are least likely to be got next based initially on the MQ message priority and pre-stages those first to SCM.
- The maximum amount of augmented storage (estimated) required should all of the SCM storage be used is 77,455MB. This means that if the Coupling Facility does not have this much free space, it will be possible to run out of space in the CF before the SCM storage is exhausted. Currently only 0.6% of the maximum augmented space is being used.
- It is estimated that the SCM can support 613,417K entries and 3,681M of elements (a ratio of 1:6) at capacity. Currently there are 4,034K of entries and 40,343K of elements (a ratio of 1:10), which means that SCM (and the CF) will run out of elements before entries if the current message size is continued.
- In this interval there were 32,339 SCM read operations initialised transferring 33,910MB from storage class memory to CF and each read operation takes 1583 microseconds.
- In this interval there were 32,336 SCM write operations initialised transferring 33,907MB from CF to storage class memory and each took 1396 microseconds.
 - We might assume that the total amount of data is relatively flat over the interval as the amount of data read and written is similar, and indeed this is as expected as the data is taken from an interval from the “non-sequential gets from deep shared queue” section.
- The delayed faults count is the number of list item references that were delayed due to a fault condition resulting in required access to storage class memory. In this example the value is particularly high as the KeyPriority1 algorithm was unable to predict which messages would be needed. As a result there are multiple faults per request, as indicated by the %ALL value being greater than 100.
 - If the messages are being put or gotten in priority order and the number of delayed faults is high then KeyPriority1 algorithm’s performance may be impacting your application(s) however there is no system tuning available to improve the performance.

Example use cases for IBM MQ with SCM

The section in redbook “IBM MQ V8 Features and Enhancements” discusses 2 use cases for MQ with SCM:

- Improved performance. This uses SCM to increase the number of messages that can be stored on a shared queue without incurring the performance cost of using SMDS.

- Emergency storage. This uses SMDS with message offloading, in conjunction with SCM to reduce the likelihood of an MQRC_STORAGE_MEDIUM_FULL reason code being returned to an MQ application during an extended outage.

Capacity – CFLEVEL(4 and less) – no offload available - “Improved Performance”

Using SCM in conjunction with a structure defined at less than CFLEVEL(5) will ensure that when the structure reaches 90% full, messages will be pre-staged to SCM. Provided there is sufficient free space in the Coupling Facility, it will be possible to continue to put messages until either the SCM entry or element values reach 100%.

This means that for a 1TB SCM structure with sufficient CF storage for augmented space and the optimal entry to element ratio, it would be possible to store 16.7 million messages of 62KB in the CF Flash storage.

Capacity – CFLEVEL(5) Offload - “Emergency Storage”

When an MQ structure is defined at CFLEVEL(5) and the offload threshold for a particular message size has been exceeded, MQ will store 1 entry and 2 elements in the CF, which is the MQ implementation header plus approximately 130 bytes of message data, as well as writing the remaining message data to the offload media e.g. SMDS.

Given the maximum capacity of a Shared Message Data Set associated to a queue manager is 16TB and up to 31 queue managers may be connected to the structure, the combined SMDS for a single structure may hold 496TB of messages.

This means that for a 1TB SCM structure with sufficient CF storage for augmented space where all messages are offloaded to SMDS and the optimal entry to element ratio (1:2), it would be possible to store 14,310 million messages of 62KB in a combination of CF, SCM and SMDS storage.

Please refer to the “[MP1H: WebSphere MQ for z/OS V7.1.0 Performance Report](#)” for a comparison of throughput rates for CF and SMDS.

Capacity – CFLEVEL(5) – no offload - “Improved Performance”

In order to configure the structure for *improved performance* when using CFLEVEL(5), it is necessary to set the OFFLDnSZ attributes to 64K e.g.:

OFFLD3SZ(64K) OFFLD3TH(90)

This disables offload threshold 3, so would never offload messages less than 4KB to SMDS. This means that using the default rules only messages of 4KB or larger will be offloaded to SMDS. due to the first 2 offload rules. Messages smaller than 4KB will be written in their entirety to CF (for pre-staging to SCM).

Performance / Scalability

Does the CF Structure attribute “CFLEVEL” affect performance?

From version 7.1.0, IBM MQ supports 5 values for CFLEVEL for an application structure.

1. CFLEVEL(1) – Non-Persistent messages less than 63KB.
2. CFLEVEL(2) – Non-Persistent messages less than 63KB.
3. CFLEVEL(3) – Persistent and non-persistent messages less than 63KB.
4. CFLEVEL(4) – Persistent and non-persistent messages up to 100MB.
5. CFLEVEL(5) – As CFLEVEL(4) but allows tiered offloading when coupling facility fills and offload choice of DB2 or SMDS.

Persistent messages can only be used with shared queues when the CFLEVEL attribute is set to 3 or higher and in conjunction with the RECOVER(YES) attribute.

Using CFLEVEL 3 or higher and RECOVER(YES) means that in the event of the Coupling Facility failing, the CF structures can be recovered from the last backup point to just prior to the point of failure.

Using CFLEVEL 3 or higher with RECOVER(NO) means that in the event of the Coupling Facility failing, the messages will be lost. Since these can only be non-persistent messages, and recovery of these messages is not paramount, it is not an unacceptable occurrence.

Measurements using non-persistent messages both in and out-of-syncpoint have shown no significant degradation on throughput nor increase on cost per transaction when using higher CFLEVEL values over a structure that has been defined with CFLEVEL(2).

Using CFLEVEL(5) offers multiple benefits including increased capacity in the CF for messages less than 63KB and significantly improved performance for messages greater than 63KB than the DB2 alternative.

The impact on MQ requests of the CURDEPTH 0 to 1 transition

The 0 to 1 transition in the current depth of a shared queue can affect the cost and throughput of MQ messages.

When an application opens a shared queue for input, the queue manager registers an interest in the queue. This tells XCF to notify the queue manager when certain events occur with this queue. One of these events is when the depth of the queue goes from zero to one – i.e. a message is available on a previously empty queue. When this happens, XCF signals each queue manager that has previously expressed an interest in the queue that there is now a message available. When the signal occurs an SRB task is run within the queue manager that checks to see if additional work needs to be done. By contrast, when the depth of the queue goes from one to two (or more), XCF does not signal all interested queue managers.

Consider the case of a server application processing messages – when there is a low throughput, there are insufficient messages to keep the server application busy. This means that the queue's depth may frequently change from zero to non-zero. This will result in additional CPU being used when XCF signals the zero to one transition.

For example, if there are 10 requester applications connected to 10 queue managers that put messages and get reply messages from a common reply-to queue, when the server application puts a reply message and the queue depth changes from zero, then each of the 10 queue managers will be signalled. One will process the message and the other nine will be signalled, check the request and do nothing

further. If the message rate is high enough to ensure this zero to one transition does not occur, XCF does not signal all queue managers that have registered an interest.

When would I need to use more than one structure?

There is no significant performance benefit to using more than one structure within one CF.

There is an impact if you use structures in multiple CFs when processing messages within syncpoint.

You might want to use different structures for administration and transaction isolation. For example:

- If you need to have more than 512 queues defined, you will need multiple structures
- If you have unrelated applications, you may want them to use different structures in case one application has problems and the structure fills up. If the applications are using the same structure then all the applications using the structure will be impacted. If the applications use different structures, a problem with one structure will not impact applications using other structures.
- Your structures may have different requirements, such as duplexing or recovery.
- You may want to limit the space used in the CF by different applications. You could restrict the number of messages on a queue by using queue maxdepth.
- You may want to have your business critical applications using structures on the fastest Coupling Facility, and non-business critical applications using another Coupling Facility

When do I need to add more Queue Managers to my QSG?

There are several reasons that you may need to add extra queue managers to your QSG:

1. Logging - you are being constrained by the rate at which the logs can be written to disk.
2. Channels - you are unable to start any further channels to support workload.

What is the impact of having Queue Managers active in a QSG but doing no work?

There is no significant impact of running with multiple queue managers in a QSG when only a subset of those are actually doing any work compared to running only the queue managers that are processing any work.

As an example, we compared running workload on 2 queue managers in a QSG when:

- These were the only 2 queue managers active
- When there were 12 queue managers in the QSG, and 10 were “idle”.

The CPU cost per transaction were the same in each case and the throughput dropped by less than 1% when there were 12 queue managers available (the throughput dropped from 1536 to 1526 transactions per second when using 1KB non-persistent messages).

Note: If shared queues have been defined to the IMS Bridge storage class, the “idle” queue managers will process IMS Bridge messages. For further details, see the section titled “[Putting messages from MQ into IMS](#)”.

What is a good configuration for my shared queues?

In this section, many shared queue considerations have been discussed. For the simplest case, we would advise that there are a minimum of 2 application structures:

- One application structure can be used for non-persistent messages and can be configured with CFLEVEL(3)² or the highest supported CFLEVEL as this structure does not need to be backed up. This will reduce recovery times.
 - Since these are non-persistent messages (i.e. not critical to the business) is there really any need to duplex this structure? Duplexing a structure will reduce the through-put and increase the cost of the transaction.
 - Using CFLEVEL(3) or higher with RECOVER(NO) means that only non-persistent messages up to 63KB can be put to queues defined in this structure.
 - If large (i.e. greater than 63KB) non-persistent messages need to be stored in shared queues, the structure will need to be defined with CFLEVEL(4). Again by setting the RECOVER(NO) attribute, only non-persistent messages can be put to queues defined on this application structure.
 - If there is a requirement for a large capacity, use CFLEVEL(5) with offload to SMDS as this will allow the system to offload messages to the shared message data sets when the CF usage reaches the tiered offload thresholds.
 - If large messages are being used, CFLEVEL(5) offers a significantly less expensive offload option than DB2.
- The other application structure can be used for persistent messages and set to a higher CFLEVEL (or RECOVER(YES) if already using CF level 3 or higher) such that it may be backed up in the event of a failure. If desired it may be duplexed, either to a local secondary CF or to a physically remote coupling facility.
- Do you really need to cross application structures when running in-syncpoint? Bear in mind that there is an associated cost when crossing structures.
- If more than 2 application structures are required, consider the use of them – do they need to be duplexed? Do they need to be backed up in case of a failure of the CF?
- If running with a duplexed application structure it is advisable to have the CSQ_ADMIN structure duplexed too.

Shared queue persistent messages

Throughput for persistent messages in shared queues is ultimately dependent on the MQ log bandwidth of each queue manager in the queue sharing group. Additionally it depends on general shared queue considerations as follows

Shared queue performance affecting factors

- For messages up to 63KB (64512 bytes)
 - z/OS heuristics which can change CF calls from synchronous to asynchronous
 - The type of link(s) between individual z/OS's and the CF(s).
 - This affects the elapsed time to complete CF calls and so influences the heuristics.

² CF level 3 onwards is specified as in the event of a coupling facility failure, the queue manager will remain available.

- The CF machine type and CF CPU %BUSY
- For messages larger than 63KB
 - As above for up to 63KB messages plus the throughput performance of the DB2 data sharing group tablespace used to store these messages.

The performance affect of these factors can vary significantly from one machine range to another.

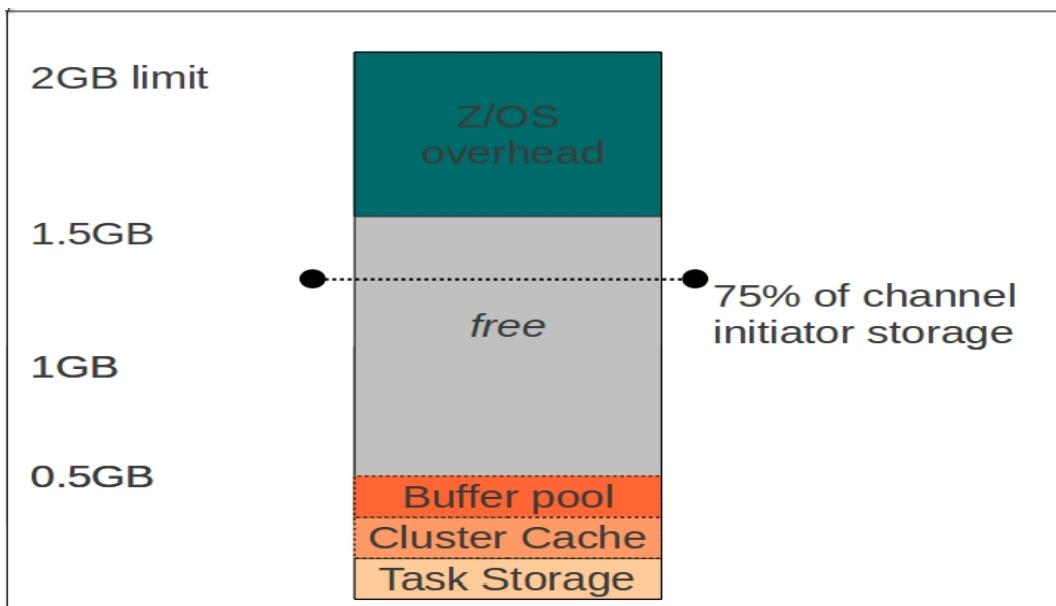
Chapter 3

Channel Initiator

What is the capacity of my channel initiator task?

The channel initiator address space is limited to 2GB of storage and this storage is used for tasks and memory usage. The diagram below shows how the storage within the address space can be used:

Channel initiator storage usage



Notes:

- This above diagram is not an address space map. The coloured blocks indicate approximate relative sizes only. In addition the “z/OS overhead” includes fixed ECSA allocation.
- Task storage consists of adapters, dispatchers, SSL tasks, DNS task and pub/sub tasks.
- The cluster cache stores data about cluster subscriptions. If the queue manager does not have any cluster channels defined, this storage will not be allocated. The storage usage may vary – if the CLCACHE is set to STATIC, 2MB will be used but if CLCACHE is DYNAMIC, the storage usage is 2MB but may grow.

- The buffer pool usage is explained in the following section but does not relate to the queue manager buffer pool usage and the size may change depending on a number of factors including message sizes.
- Storage usage can be tracked by the CSQX004I message that appears in the channel initiator on an hourly basis unless the storage is used more rapidly.

Version 8.0 introduced channel accounting and statistics, which uses storage from above the 2GB bar, so does not impact the number of channels that the channel initiator is able to support.

Channel initiator task storage usage

In version 8.0, the storage used by each task type can be estimated as:

- Adapter 223KB
- Dispatcher 248KB
- SSL Task 1.3MB

What limits the maximum number of channels?

The maximum number of channels is limited by:

- Channel initiator virtual storage in the extended private region (EPVT) which applies to all channel types including CHLTYPE(SVRCOMM) channels (thin clients)
- Possibly, by achievable channel start (or restart after failure) and stop rates and costs. These increase with the number of channels represented in the SYSTEM.CHANNEL.SYNCQ.

In WebSphere MQ for z/OS version 6.0.0 and earlier, every non-SSL channel uses about 140 KB and every SSL channel about 170KB of extended private region in the channel initiator (CHINIT) address space. Storage is increased if messages larger than 32 KB are being transmitted. This increased storage is freed when either a sending or thin client channel requires less than half the current buffer size for 10 consecutive sends or a heartbeat is sent or received.

WebSphere MQ for z/OS version 7.0.0 introduced the concept of channel initiator buffer pools where a pool of storage is maintained per dispatcher task. The size of the message being processed by the channel initiator directly affects the size of the memory footprint. When the channel initiator determines that there is a shortage of storage available, the channel initiator will attempt to release some of the allocated storage pools.

The upper limit is likely to be around 9000 non-SSL or 9000 SSL channels on many systems as EPVT size is unlikely to exceed 1.6GB.

How many channels can a channel initiator support?

This depends on the size of the messages flowing through the channel.

A channel will hold onto a certain amount of storage for its lifetime. This footprint depends on the size of the messages.

Message Size	1KB	32KB	64KB	1MB
Footprint per Channel	90	99	109	1125
Overhead of Message Size increase on 1KB messages		+9K	+18K	+1034K

If the message size over a channel varies significantly, the effect of channel initiator buffer pools can play a more significant effect.

For example, running 1000 channels with 1KB messages and 50 channels with 64KB messages would use:

- 90KB * 1000
- 109KB * 50
- Which gives a total of 95,450KB, out of the “free storage”

How many SVRCONN channels can a channel initiator support?

The following table shows the footprint of a SVRCONN channel being run. This is shown in KB per channel.

SHARECNV	1KB Messages	32KB Messages	64KB Messages
0	96	166	196
1	179	291	357
10 where each channel instance has 10 shared conversations	242	685	1031

NOTE: With 1KB messages, a SVRCONN channel defined with SHARECNV 10 (or greater) will use approximately 24.2KB per shared conversation (CURSHCNV). This means that if a SVRCONN channel is defined with SHARECNV(1000) but has only 10 shared conversations (as reported by DIS CHS(*) CURSHRCNV), the footprint would be 242KB for the channel (or 24.2KB per conversation).

On a system that has an EPVT size of 1.6GB, this means that running server-connection type channels with SHARECNV(0) with 1KB messages, the maximum number of clients that can be connected should be able to reach the IBM MQ defined limit for MAXCHL of 9,999.

For a server-connection channel with a SHARECNV value of 1, it would require 1747MB of storage to start 9,999 channels, so the maximum number of channels would be 9,370.

However, if shared conversations are being used on a server-connection channel with SHARECNV value of 10, it is possible to have 6,930 channels running – with 69,300 conversations.

If the greater memory usage of using a non-zero SHARECNV channel outweighs the benefits such as client heartbeating, read ahead (as allowed using the queue attribute “DEFREADA”) and client asynchronous consume, it is advised to alter the default SVRCONN channel definition to specify SHARECNV(0).

For multi-threaded clients running at version 7.0 or later, e.g. Java applications, define an additional SVRCONN channel with SHARECNV(10) and ensure that these multi-threaded clients use the new channel.

Does SSL make a difference to the number of channels I can run?

Yes. Typically SSL uses an additional 30KB for each channel but for messages larger than 32KB can be higher.

Channel initiator buffer pools

In WebSphere MQ version 7, the concept of channel initiator buffer pools were introduced. These are typically used when the size of the messages flowing across the channels varies significantly.

Each dispatcher has a pool of storage buffers available to handle requests.

In addition, there is a global pool for large storage requests which are shared across all dispatchers.

The dispatcher buffer pools handle requests up to 36KB which allows a full 32KB buffer to be held (which is a common size at the dispatcher level). The dispatcher buffers work with a range of sizes:

- 4KB
- 8KB
- 16KB
- 32KB
- 36KB

The size selected is based upon the required size and the channel initiator searches the available buffers. If no buffer is available of the appropriate size, the next size up is checked. If no buffers are available, a new buffer will be allocated.

The global pool has a set of buffer pools with sizes:

- 64KB
- 128KB
- 256KB
- 512KB
- 1MB
- Larger than 1MB

Each buffer pool, whether a dispatcher or global buffer pool, except the “larger than 1MB” buffer may have up to 50 free buffers in addition to in-use buffers and the usage will depend on how many buffers are actually busy. The “larger than 1MB” buffer pool may only have up to 5 free buffers, so the “larger than 1MB” free buffer pool may vary in size up to 500MB¹, but the “in-use” pool may be as large as the channel initiator can support.

Q+A: What uses a buffer pool buffer?

Typically a SVRCONN channel may have 3 buffers and an MCA channel may have 2 buffers – one for getting / putting the message and a second buffer for sending/receiving the message from the communications protocol.

As previously mentioned a started channel will hold onto storage for its life-time so unless the message sizes significantly change, the buffer pool usage will not vary greatly.

Q+A: What happens when my channel stops?

When a channel stops, the associated buffers are released back to the buffer pools. This can make the storage footprint appear higher than expected as the storage is not released until the channel initiator determines that it has reached 75% utilised and drives its scavenger task. For example, if a channel is started to send 100MB messages, upon ending, the storage will be returned to the global buffer pool and will not be freed immediately. This will mean that the CSQX004I message will still

¹Based on a maximum message size of 100MB

include the 100MB buffers in its calculation even though the 100MB buffers may not be in use at the time.

What happens when the channel initiator runs out of storage?

The messages logged by the channel initiator reporting storage usage should mean that storage becoming constrained is not a surprise.

Given the nature of the buffer pools, some variation in storage usage should be expected if a widely varying message size is seen through-out a period of time. It may be that typical day-time workload involves smaller messages and over night, there is a time where a set of large messages are flowed. In this case, it may be observed that the scavenger task is started to release storage that is allocated but not in use.

If a dispatcher attempts to process a message requiring a large buffer and there is insufficient space available and the scavenger hasn't been given time to run, the dispatcher task will fail, resulting in the CSQX112E message being logged, e.g. "[CSQX112E @VTS1 CSQXDISP Dispatcher process error, TCB=xxxxxxxx reason=0C4000-00000004](#)". Manually restarting the channel should resolve this problem provided sufficient storage is available.

If the scavenger message (CSQX068I) is appearing occasionally, this suggests that the channel initiator is running with its optimum working set of buffer pool sizes which changes when larger messages are flowed.

If the scavenger message is occurring frequently, this suggests that the channel initiator address space does not have sufficient capacity for the workload being run and an additional channel initiator (and associated queue manager) may be required.

Channel Initiator Scavenger Task

As previously mentioned, the channel initiator reports the memory usage on an hourly basis and more often when the storage usage increases significantly.

As part of this storage monitoring, the channel initiator will start a scavenger process if the total memory usage reaches or exceeds 75% of the available storage to release the free buffers from the channel initiator buffer pools.

If the channel initiator only uses long-running channels, the scavenger task may not be started for up to 1 hour after detecting the storage change.

NOTE: The X004I message is logged on an hourly interval or when the storage usage changes by more than 2%. The scavenger task is initiated following the storage usage exceeding 75% and the subsequent logging of the X004I message. If the buffers are still in use when the scavenger tasks is started, it will be unable to free any storage and so will only be able free those buffers when the workload is complete. Typically this is driven by a message on the SYSTEM.CHANNEL.INITQ (e.g. start channel) or a subsequent change in storage usage. If no channel state changes occur, it may be an hour before the channel initiator attempts to free available buffers. This can be circumvented by stopping and restarting a channel.

The scavenger task will release all buffer pool storage marked as free except for 1 buffer of 4KB and 1 buffer of 36KB per dispatcher.

Defining channel initiator - CHINIT parameters

The ALTER QMGR parameters CHIADAPS and CHIDISPS define the number of TCBS used by the channel initiator. CHIADAPS (adapter) TCBs are used to make MQI calls to the queue manager. CHIDISPS (dispatcher) TCBs are used to make calls to the communications network. The ALTER QMGR parameter MAXCHL can influence the distribution of channels over the dispatcher TCBs.

CHIADAPS

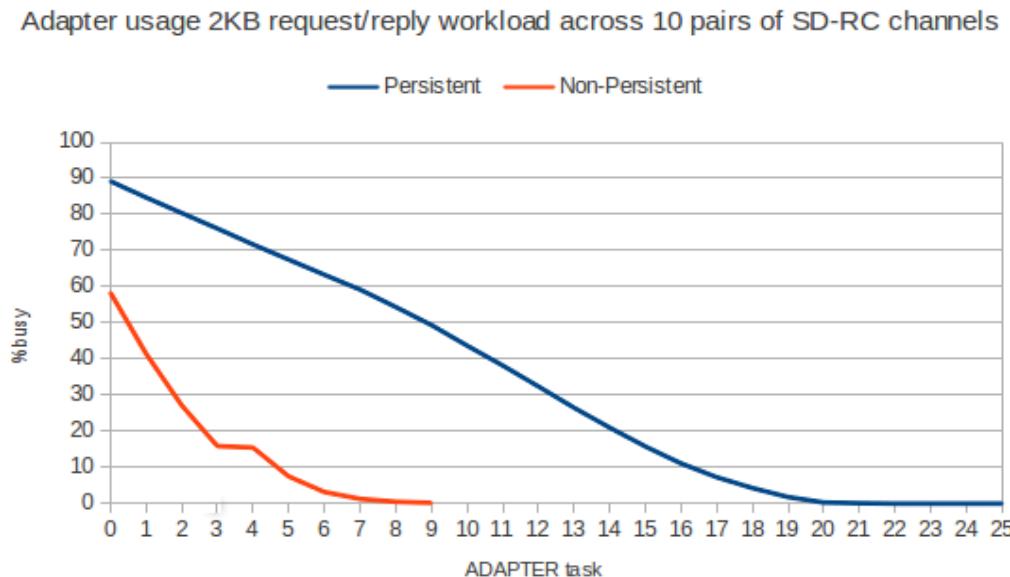
Each MQI call to the queue manager is independent of any other and can be made on any adapter TCB. Calls using persistent messages can take much longer than those for non-persistent because of log I/O. Thus a channel initiator processing a large number of persistent messages across many channels may need more than the default 8 adapter TCBs for optimum performance. This is particularly so where achieved batchsize is small, because end of batch processing also requires log I/O, and where thin client channels are used.

For heavy persistent workloads we recommend CHIADAPS(30) for systems with up to 4 processors and then increase CHIADAPS by 8 for each additional processor up to a maximum of CHIADAPS(120). We have seen no significant disadvantage in having CHIADAPS(120) where this is more adapter TCBs than necessary.

IBM MQ version 8 introduced channel statistics via the use of TRACE(S) CLASS(4). These can be used to determine whether there are sufficient adapter tasks defined to a channel initiator.

The channel initiator uses a pool of adapter tasks and when a request is made, the next available adapter task is used. This results in adapter 0 typically being the most used adapter.

For example the following chart is generated from the adapter reports resulting from workloads using 2KB messages in a request/reply model with 10 outbound and 10 inbound sender-receiver channel pairs where the message persistence is varied.



The preceding chart shows how busy each adapter task is over a 60 second interval.

The non-persistent workload shows that only 8 adapters (0-7) are used and only adapter 0 is more than 50% utilised. For non-persistent messages, the tasks are primarily using CPU.

The persistent workload shows adapters 0 through 9 are greater than 50% busy with the usage tailing off until adapter 18 is less than 5% busy. In this case, the adapter tasks are primarily waiting for log I/O to complete and whilst this occurs, the tasks are blocked.

A client task that selects messages using message properties can also result in CPU intensive work on an adapter task and there may be benefit in additional adapter tasks in that environment.

Generally, if all the adapter tasks are being used, there may be requests queued waiting for an adapter, so more adapters may offer some benefit to throughput.

CHIDISPS and MAXCHL

Each channel is associated with a particular dispatcher TCB at channel start and remains associated with that TCB until the channel stops. Many channels can share each TCB. MAXCHL is used to spread channels across the available dispatcher TCBs.

The first([MIN\(\(MAXCHL / CHIDISPS \) , 10 \)](#)) channels to start are associated with the first dispatcher TCB and so on until all dispatcher TCBs are in use. The effect of this for small numbers of channels and a large MAXCHL is that channels are NOT evenly distributed across dispatchers.

We suggest setting MAXCHL to the number of channels actually to be used where this is a small **fixed** number.

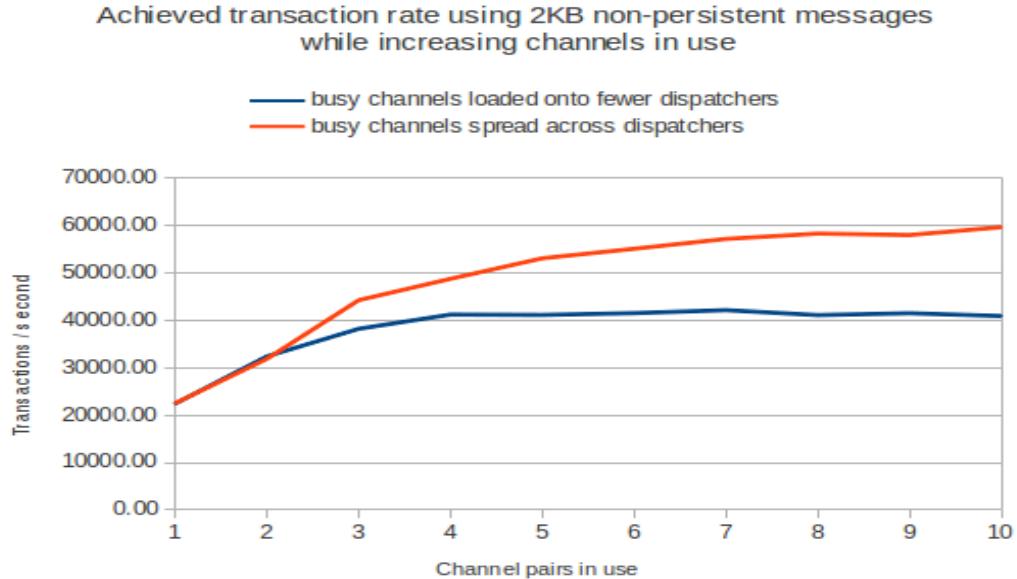
IBM MQ version 8 introduced channel statistics via the use of TRACE(S) CLASS(4). These can be used to determine whether there are sufficient dispatcher tasks defined to a channel initiator.

Performance report “[MP1B](#)” provides an application, MQSMF, that generates a dispatcher report which can show the usage of each dispatcher. If the report shows dispatchers that have little or no usage co-existing with dispatchers that are showing high usage, the MAXCHL to CHIDISPS ratio may be too high.

For best performance from dispatchers, the system should use as few dispatcher tasks as possible provided they are not being used at capacity. Where larger numbers of channels are being used, we suggest reviewing the dispatcher report but where this is not available, setting CHIDISP(20) where there are more than 1000 channels in use. We have seen no significant disadvantage in having CHIDISPS(20) where this is more dispatcher TCBs than necessary.

The load on each dispatcher can make a difference to the total throughput of the channel initiator. For example the following chart shows the achieved transaction rate with a request/reply workload using 2KB messages as more channels are used. In both cases, there were 3 dispatcher tasks defined.

In these tests, MAXCHL(150) and CHIDISPS(3) were defined.



This means that if all 150 channels were started, there would be 50 channels per dispatcher.

In this test there were 100 channels started but only a subset of channels were actively sending messages as indicated by the x-axis on the chart.

When the busy channels were all on the same dispatcher, the throughput peaked at 40,000 transactions per second even though the dispatcher was 58% busy at its peak.

When the busy channels were shared across all 3 dispatchers, the peak throughput was 50% higher and two of the three dispatchers achieved a higher percent busy than the single dispatcher in the original measurement.

The use of channel compression can affect how many dispatcher tasks are required.

For example the following table shows the report cost of processing a 32KB message that is approximately 40% compressible in the dispatcher task report:

Compression type	CPU microseconds per dispatcher request
None	6
ZLIBFAST (hardware compression ²)	13
ZLIBHIGH (software compression)	219

Checking the OMVS Environment

Each channel initiator task uses a number of OMVS threads. Within the channel initiator address space there will be **3³** plus “CHIDISPS” plus “SSL Tasks” OMVS threads.

Use command “D OMVS,LIMITS” and review the value of MAXPROCSYS. If the act of adding a new channel initiator or amending an existing one causes the number of MAXPROCSYS to be close to the maximum value, then MAXPROCSYS should be increased.

²IBM MQ version 8.0 added support for zEDC hardware compression for the ZLIBFAST channel compression option. This is detailed further in performance report “MP1J”.

³ This is based on an OMVS thread for CSQXJST, and 2 for CSQXRCTL – one of which is a listener thread for incoming requests directed at the queue manager.

The SETOMVS command can be used to dynamically change the value, or the value can be updated in the BPXPRMxx parameter values.

Effect of Changing CHIDISPS

By increasing the CHIDISPS attribute, the number of dispatcher processes is increased. This can be seen in SDSF© using the “PS” option.

If the change is significant or affects a large number of queue managers, these additional processes may cause the system-wide limits set for MAXPROCSYS and MAXPROCUSER to be exceeded. This can be seen when the following messages are logged:

```
BPXI039I SYSTEM LIMIT MAXPROCSYS HAS REACHED 100% OF ITS CURRENT CAPACITY  
BPXI040I PROCESS LIMIT MAXPROCUSER HAS REACHED 100% OF ITS CURRENT CAPACITY
```

Both MAXPROCSYS and MAXPROCUSER are controlled by the BPXPRMxx parameter.

MAXPROCSYS specifies the maximum number of processes that can be active at the same time.

MAXPROCUSER specifies the maximum number of OMVS threads that a single user (i.e. the same UID) can have concurrently active. The channel initiators threads count towards this value, i.e. if there are 10 channel initiators with the same started task userid, and each one has 10 dispatchers, there will be 130 threads for the userid.

When increasing the CHIDISPS value, we recommend amending both the MAXPROCSYS and MAXPROCUSER values by:

MAXPROCxxx = MAXPROCxxx + (Increase in CHIDISPS x Queue managers being amended)

Where xxx is SYS and USER

Tuning Channels

There are a number of options that can be applied to channels that can reduce cost or help identify problems in the appropriate environment.

Channel option BATCHHB

This attribute specifies whether batch heartbeats are to be used. These allow the sending channel to verify that the receiving channel is still active just before committing a batch of messages. If the receiving channel is not active the batch can be backed out rather than becoming in-doubt. By backing out the batch, the message remain available for processing so they could, for example, be redirected to another channel.

Channel option BATCHINT

The minimum time in milliseconds that a channel keeps a batch open. The batch is terminated when one of the following conditions is met:

- BATCHSZ messages are sent
- BATCLIM kilobytes are sent
- The transmission queue is empty and BATCHINT is exceeded.

Channel option BATCLIM

The limit in kilobytes of the amount of data that can be sent through a channel before taking a sync point. A sync point is taken after the messages that caused the limit to be reached flows across the channel.

The default is 5000KB, so if large messages are flowing across the channels, a sync point make be taken after only a small number of messages – possibly after every message.

Channel option BATCHSZ

This attribute is the maximum number of messages that can be sent through a channel before taking a sync point.

The maximum batch size used is the lowest of the following values:

- The BATCHSZ of the sending channel.
- The BATCHSZ of the receiving channel.
- On z/OS, three less than the maximum number of uncommitted messages allowed at the sending queue manager (or one if this value is zero or less). On platforms other than z/OS, the maximum number of uncommitted messages allowed at the sending queue manager, or one if this value is zero or less.
- On z/OS, three less than the maximum number of uncommitted messages allowed at the receiving queue manager (or one if this value is zero or less). On platforms other than z/OS, the maximum number of uncommitted messages allowed at the receiving queue manager, or one if this value is zero or less.

Channel option COMPHDR

The header data sent over a channel can be compressed using this value.

The most noticeable effect of compressing the header will be observed with small messages, for example:

- sending a 4MB message and only compressing the header, will reduce the total data sent by approximately 300 bytes.
- Sending a message of 100 bytes with a 480 byte header and compressing the header will result in reducing the data sent by approximately 300 bytes – down by 50%.

Channel option COMPMMSG

This is the list of message data compression techniques supported by the channel.

Typically channel compression is used on high-latency networks or low-bandwidth networks as there is a cost associated with compressing and decompressing the message being sent.

As the compression is performed by a channel dispatcher task, this can add extra workload on the dispatcher task and it would be advisable to re-evaluate the optimal setting of channels to dispatchers ratio.

The zEC12 and zBC12 classes of System z hardware introduced hardware compression using zEnterprise Data Compression (zEDC).

IBM MQ version 8.0 added support for hardware compression via the channel compression option “ZLIBFAST”. Compressing messages using zEDC hardware compression can reduce the message costs by 80% compared to compression performed in software.

For further information on version 8.0 channel compression enhancements both from using software compression, when zEDC is not available, and hardware compression refer to performance report “[MP1J](#)”. In particular review the information in:

- Appendix A Regression – Moving messages across Channels
- Channel Compression using zEDC.

Channel option DISCINT

The minimum time in seconds the channel waits for a message to arrive on the transmission queue. The waiting period starts after a batch ends. After the end of the waiting period, if there are no more messages, the channel is ended.

A value of 0 causes the message channel agent to wait indefinitely. See the section on channel start/stop rates and costs to see the effect of channels changing state.

Channel option HBINT

This specifies the approximate time between heartbeat flows sent by a message channel agent (MCA). These flows are sent when there are no messages on the transmission queue with the purpose of unblocking the receiving MCA, which is waiting for messages to arrive or for the disconnect interval to expire. When the receiving MCA is unblocked, it can disconnect the channel without waiting for the disconnect interval to expire. Heartbeat flows also free any storage blocks that are allocated for large messages and close any queues that are left open at the receiving end of the channel. To be most useful, the value needs to be less than the DISCINT value.

Channel option KAINT

The value passed to the communications stack for keepalive timing for this channel.

Channel option MONCHL

This attribute controls the collection of online monitoring data for channels. Changes to this parameter take effect only on channels started after the change occurs.

Channel option NPMSPEED

This attribute specifies the speed at which non-persistent messages are to be sent.

- FAST means than non-persistent messages are not transferred within transactions. Messages might be lost if there is a transmission failure or the channel stops whilst the messages are in transit.
- NORMAL means normal delivery for non-persistent messages.

If the value of NPMSPEED differs between the sender and receiver or either one does not support it, NORMAL is used.

SVRCONN channel option SHARECNV

Specifies the maximum number of conversations that can be sharing each TCP/IP channel instance. High SHARECNV limits have the advantage of reducing queue manager thread usage. If many conversations sharing a socket are all busy, there is a possibility of delays. The conversations contend with one another to use the receiving thread. In this situation, a lower SHARECNV value is better.

Tuning channels - BATCHSZ, BATCHINT, and NPMSPEED

To get the best from your system you need to understand the channel attributes BATCHSZ, BATCHINT and NPMSPEED, and the difference between the batch size specified in the BATCHSZ attribute, and the achieved batch size. The following settings give good defaults for several scenarios:

1. For a synchronous request/reply model with a low message rate per channel (tens of messages per second or less), where there might be persistent messages, and a fast response is needed specify BATCHSZ(1) BATCHINT(0) NPMSPEED(FAST).
2. For a synchronous request/reply model with a low message rate per channel (tens of messages per second or less), where there are only non-persistent messages, specify BATCHSZ(50) BATCHINT(10000) NPMSPEED(FAST).
3. For a synchronous request/reply model with a low message rate per channel (tens of messages per second or less), where there might be persistent messages and a short delay of up to 100 milliseconds can be tolerated specify BATCHSZ(50) BATCHINT(100) NPMSPEED(FAST).
4. For bulk transfer of a pre-loaded queue specify BATCHSZ(50) BATCHINT(0) NPMSPEED(FAST).
5. If you have trickle transfer for deferred processing, (the messages are typically persistent) specify BATCHSZ(50) BATCHINT(5000) NPMSPEED(FAST).
6. If you are using large messages, over 100000 bytes you should use a smaller batch size such as 10, and if you are processing very large messages such as 1 MB, you should use a BATCHSZ(1).
7. For messages under 5000 bytes, if you can achieve a batch size of 4 messages per batch then the throughput can be twice, and the cost per message half that of a batch size of 1.

How batching is implemented

The text below describes the processing to send one batch of messages:

DO until BATCHSZ messages sent OR (xmitq empty AND BATCHINT expired)

OR BATCHLIM kilobytes sent

- Local channel gets a message from the transmission queue
 - If message is non-persistent and channel is NPMSPEED(FAST):
 - Outside of syncpoint
 - Otherwise:
 - Within syncpoint
 - Adds a header to the message and sends using TCP/IP, APPC, etc.
- Remote channel receives each message and puts it
 - If message is non-persistent and channel is NPMSPEED(FAST):
 - Outside of syncpoint
 - Otherwise:
 - Within syncpoint

END

COMPLETE channel synchronisation logic.

Thus,

- A batch will contain at most BATCHSZ messages.
- If the transmission queue is emptied before BATCHSZ is reached and the BATCHINT(milliseconds) time has expired since the batch was first started, the batch will be terminated.
- The achieved batch size is the number of messages actually transmitted per batch. Typically for a single channel the achieved batch size will be small, often with just a single message in a batch, unless BATCHINT is used. If the channel is busy or the transmission queue is pre-loaded with messages, then a higher achieved batch size might be achieved.
- Each non-persistent message on an NPMSPEED(FAST) channel is available immediately it is put to a queue at the receiver, it does not have to wait until end-of-batch. Such messages are known as 'fast messages'.
- All other messages only become available at the end-of-batch syncpoint.

NOTES:

- Fast messages can be lost in certain error situations, but never duplicated.
- All other message delivery remains assured once and once only.
- If batch reaches BATCHSZ then an end-of-batch indicator flows with last message.
- If the batch is terminated because the transmission queue is empty, or the BATCHINT interval expires, then a separate end-of-batch flow is generated.
- Channel synchronisation logic is expensive. It includes log forces where there are persistent messages or NPMSPEED(NORMAL) channels and an end-of-batch acknowledgement flow from the receiver back to the sender. A low achieved batch size results in much higher CPU cost and lower throughput than a high achieved batch size, as these overheads are spread over fewer messages.

Setting NPMSPEED

For non-persistent messages choosing NPMSPEED(FAST) gains efficiency, throughput and response time but messages can be lost (but never duplicated) in certain error situations. Of course non-persistent messages are always lost in any case if a queue manager is normally stopped (or fails) and then restarted. Thus any business process using non-persistent messages must be able to cope with the possibility of lost messages. For persistent messages NPMSPEED has no effect.

If you have applications with both persistent and non-persistent messages which rely on message arrival sequence then you must use NPMSPEED(NORMAL). Otherwise a non-persistent message will become available out of sequence.

NPMSPEED(FAST) is the default and is usually the appropriate choice, but do not forget that the other end of the channel must also support and choose NPMSPEED(FAST) for this choice to be effective.

Determine achieved batch size using MONCHL attribute

The channel attribute "MONCHL" controls the collection of online monitoring data for channels.

By default, a channel is defined with MONCHL(QMGR). This means that monitoring data is collected for a channel based on the setting of the queue managers MONCHL attribute.

Changes to the value of the channel attribute MONCHL only take effect on channels started after the change is applied.

By altering the queue managers MONCHL attribute to one of the following values LOW, MEDIUM or HIGH, the “[DISPLAY CHSTATUS\(channel\) XBATCHSZ](#)” command can be used to display the size of batches achieved over the running channel.

NOTE: Do not use DISPLAY CHSTATUS (*) when you have many channels unless necessary, as this is an expensive command. It might require many hundreds, or thousands, of pages in buffer pool 0. Buffer pool 0 is used extensively by the queue manager itself and thus overall performance can be impacted if pages have to be written to and read from the page data sets as a result of a shortage of free buffers.

Setting BATCHSZ and BATCHINT

Consider the following 3 types of application scenario when choosing BATCHSZ and BATCHINT.

1. **Synchronous Request/Reply**, where a request comes from a remote queue manager, the message is processed by a server application, and a reply sent back to the end user.

- This usually implies a short response time requirement.
- Response time requirements often preclude use of a non-zero BATCHINT for channels moving persistent messages.
- Volumes on each channel might be so small that end-of-batch will occur after nearly every message even at peak loads.
- For persistent messages, absolute best efficiency might then be achieved with BATCHSZ of 1 as there is then no separate end-of-batch flow from sender to receiver. Savings of up to 20% of the CPU cost of receiving a message and sending a reply message are typical for small messages.
- If your volumes and response time requirements permit then set BATCHSZ to x and BATCHINT to y where you typically expect x or more messages in y milliseconds and you can afford the up to y milliseconds delay in response time on that channel.
- Conclusion, for channels moving any persistent messages is:- Use the defaults unless you really know better!
- Non-persistent messages on an NPMSPEED(FAST) channel are available immediately they are received regardless of BATCHINT or BATCHSZ. So a non-zero BATCHINT is appropriate for any NPMSPEED(FAST) channel carrying ONLY non-persistent messages.
 - For example, if you expect 30 non-persistent messages per second, set BATCHINT to 2000 (2 seconds) then you will almost always achieve a batch size of 50 (assuming BATCHSZ of 50).
 - The CPU cost saving per message moved is likely to be of order 50% versus that for achieved batch size of 1 compared to achieved batch size of 50.

2. **Bulk transfer of a pre-loaded transmission queue.**

- Usually implies high volumes, a high throughput requirement but a relaxed response time requirement (e.g. many minutes is acceptable). Thus a large BATCHSZ is desirable.
- The default BATCHSZ of 50 will give relatively high throughput.
- Higher BATCHSZs can improve throughput, particularly for persistent messages (and non-persistent messages on NPMSPEED(NORMAL) channels). But might be inappropriate for very large messages sizes, where a failure in mid batch could cause significant reprocessing time.
- Do not use BATCHSZ > 100 even for messages up to 5KB.
- Do use BATCHSZ = 1 for 1MB or larger messages as anything larger tends to increase the CPU costs, and can have an impact on other applications.
- BATCHINT should be left to the default of 0.

3. **Trickle transfer for deferred processing**

- You want to transfer the messages as they are generated as cheaply and efficiently as possible. These messages are then either stored for processing in a batch window or are processed as they arrive but it is acceptable that several seconds or minutes elapse from the time the messages were first generated.
- If possible wait until a batch size of 50 is completed. This would require that you set BATCHINT to xxxx milliseconds, where more than 50 messages are generated within xxxx milliseconds (assuming BATCHSZ greater than or equal to 50).
 - If you left BATCHINT at 0 then you would probably achieve an average batch size of less than 2 whatever the setting for BATCHSZ. In fact, it is typical that nearly all the batches would consist of just 1 message.
 - This would cost significantly more CPU and logging and some more network traffic than 1 batch of 50 messages.
- Or, consider the case where you expect an average of 20 or more messages per minute and you can accept up to 1 minute delay before these messages are processed. Then:
 - If you set BATCHINT to 60000 (i.e. 1 minute) then you will achieve a batch size of 20 (on average, provided BATCHSZ greater or equal to 20)
 - If you left BATCHINT at 0 then you would probably get 20 batches of 1 message each whatever the setting for BATCHSZ.
 - 20 batches of 1 message would cost significantly more CPU and logging and some more network traffic than 1 batch of 20 messages.
- However, a very long BATCHINT is probably not appropriate as this could mean a very long unit-of-work and consequent elongated recovery time in the event of a failure. You should usually use a BATCHINT value of less than 300000 (5 minutes)

Channel Initiator Trace

TRACE(C) costs can be significant when running a high workload.

Comparing high workload over a single pair of Sender-Receiver channels, we saw between a 25% and 55% increase in the cost of the transaction.

On an idle queue manager/channel initiator, we found that TRACE(CHINIT) added 3% to the cost of running the channel initiator.

IBM MQ version 8.0 for z/OS introduced channel initiator accounting and statistics data. Enabling both of the class(4) trace options typically increases channel initiator CPU costs by 1 to 2%.

Why would I use channels with shared conversations?

When it comes to the V7 clients connecting, using a SVRCONN channel with a SHARECNV of greater than 0 allows the channel to run in V7 mode - which gives several benefits:

- Read-ahead - this allows the queue manager to effectively push messages out to the client when they are available - and the MQ client code maintains its own buffer to hold these messages until the client application is ready for them. This can reduce the line turn-around time giving better performance.
- Client Asynchronous Consume - allows the client to register an interest in multiple queues and receive a message when it arrives on any of those queues.
- Heart-beating over a SVRCONN channel - which allows the queue manager to detect when the client has gone away
- By sharing conversations from a multi-threaded client application, it is possible to decrease the footprint on the channel initiator, allowing more clients to connect.
- In V6, a single SVRCONN channel used around 140KB.
- In V7, a SVRCONN channel with SHARECNV(10) uses around 514K – which equates to each conversation using only 51KB - which allows for significantly more client conversations to be running on a single channel initiator.

There are instances where the customer may choose to run a SVRCONN channel with a SHARECNV value less than 10 for example:

- If the clients are performing persistent workload (or a mixture), they may want to run with a lower SHARECNV setting as the single channel instance will use a single adapter task. This adapter task will be blocked whilst any logging of the persistent message occurs, which can then have a direct impact on the other (non-persistent) conversations in this shared channel.
- If the clients are doing a high-volume of workload - A single channel can only flow a certain amount of data over it and this is similar to the total amount of data that can be flowed over a channel with multiple shared conversations. So if the customer was driving 50MB / second through a SVRCONN and moved to a SHARECNV(10) channel, they would not get 500MB/second through that shared channel. As a result they may want to lower the SHARECNV attribute.

There is an increase in **connection** cost when using non-zero SHARECNV SVRCONN channels of approximately 20% when compared to SHARECNV(0) channels. However when running with SHARECNV greater than 1 and it is more likely that at least one of the conversations from the client is already active, meaning the existing channel can be shared, the connection overhead decreases.

With regards to **workload**, in a like for like workload, e.g. not exploiting read-ahead, the costs are typically similar. If the user is able to use long-running connections and asynchronous puts and get, there may be a reduced transaction cost when using a non-zero SHARECNV value.

Performance / Scalability

Channel start/stop rates and costs

The rate and CPU cost at which channels can be started and stopped varies with the number of channels represented in SYSTEM.CHANNEL.SYNCQ.

A channel is represented in SYSTEM.CHANNEL.SYNCQ if it has ever been started. It will remain represented until its definition is deleted. For this reason we recommend that redundant channel definitions be deleted.

While many users do not start and stop channels with any great frequency, there may still be significant sender channel restart activity after a channel initiator failure.

The following table demonstrates the effect of the number of channels represented in SYSTEM.CHANNEL.SYNCQ on a WebSphere MQ V7.1.0 Queue Manager.

Channel pairs in .SYNCQ	Sender Channel START		Sender Channel STOP	
	Channels per second	2817-705 CPU millisecs per START	Channels per second	2817-705 CPU millisecs per STOP
1,000	268	1.3	502	1.3
2,000	228	1.65	288	1.68
4,000	176	2.14	285	2.29

NOTE: A channel pair is one CHLTYPE(SDR) and one CHLTYPE(RCVR).

SSL channel start costs

Whenever an SSL-enabled channel pair is started a cryptographic handshake is performed which establishes the authenticity of the channel partners and dynamically generates a secret cryptographic encryption key. This cryptographic handshake increases both the CPU consumption and the elapsed time for the channel start.

On our 2817-705 system we have found the additional SSL costs to be largely independent of the SSL cipherspec used. With 1000 channel pairs in SYSTEM.CHANNEL.SYNCQ, the CPU consumption was measured to be 5.6 CPU milliseconds per sender channel start. The channel start rate was 89 channels per second.

The use of the optional Crypto Express3 Coprocessor reduces the CPU costs to approximately 2.4 CPU milliseconds per sender channel start, but has no effect on the channel start rate. The average execution time on the Crypto Express3 Coprocessor for channel start was 0.96 milliseconds.

Factors affecting channel throughput and cost

- Message persistence, especially for NPMSPEED(FAST) channels
- Message size
- Achieved batch size is very significant for both throughput and cost
 - And is often much smaller than the defined BATCHSZ channel parameter
 - You need to understand what batch size your configuration will typically achieve before using the following charts to estimate possible throughput and CPU cost.
 - See “[Determine Achieved Batch Size using MONCHL attribute](#)” which discusses how the MONCHL attribute can be used in conjunction with “DISPLAY CHSTATUS(channelName) XBATCHSZ” to determine the size of the batches achieved over the running channel.
- With a pre-loaded transmission queue you can probably achieve a batch size equal to the BATCHSZ parameter setting.
- Otherwise you can probably only achieve an average batch size < 2 with most batches consisting of just 1 message, unless you can take advantage of the BATCHINT parameter.
- Message throughput is highly dependent on the configuration used:
 - Speed and utilisation of the network
 - Response time of the IBM MQ log devices
 - CPU speeds, at both ends
 - Whether messages on the transmission queue have to be retrieved from page set
- For heavy persistent workloads we recommend CHIADAPS(30) for systems with up to 4 processors and then increase CHIADAPS by 8 for each additional processor up to a maximum of CHIADAPS(120). We have seen no significant disadvantage in having CHIADAPS(120) where this is more adapter TCBs than necessary.

SSL and TLS

The use of SSL and TLS encryption increases the CPU cost of transmitting messages at both the sender and receiving end of the channel. The increased cost varies depending upon a number of factors and these costs are discussed in the following section.

When do you pay for encryption?

SSL encryption costs are incurred in the channel initiator address space at several points:

- Channel Start
- Re-negotiate secret key
- Data encryption

The cost of SSL and TLS encryption can be reduced by varying the frequency of the channel start and amount of data that flows between secret key negotiations and to a certain extent by the level of data encryption but these costs should be considered against the importance of the integrity of the data flowing over the channels.

How can I reduce the cost?

- **Change re-negotiation frequency.**

By increasing the re-negotiation frequency, the keys will be changed less often, however this means that more data will flow using the same key which in turn can give potentially more opportunity to crack the secret key.

- **Encryption level via CipherSpec**

Not all cipher specifications cost the same! Is it really necessary to use a high level of encryption with low-value data? If not, then a lower level of encryption may be appropriate.

- **Channel start/stop versus long running channels**

At channel start, the channels have to perform a handshake which includes a negotiation of secret key. If the channel is short lived and only sends a small amount of data before stopping, the secret key negotiation may be more frequent than desired.

- **Cost versus data security**

It should be determined by the company or companies using the channels whether data security is more important than the cost of encrypting the data.

- **Offloading work onto Crypto Express cards**

- The use of System SSL by IBM MQ for z/OS means that only secret key negotiations can be offloaded onto cryptographic coprocessor or accelerators.
- The data encryption and hashing is not eligible for offloading. Where possible⁴, this is performed by CPACF's (Central Processor Assist Cryptographic Function), which on zEnterprise EC12 there is 1 for each core and earlier hardware such as zEnterprise 196 shared 1 CPACF between 2 cores. Data encryption and hashing will see additional CPU usage in the channel initiator address space.
- A Crypto Express-3 coprocessor can support from 1800 to 3200 operations per second depending on the functions being executed.⁵

⁴Some cipher specs are not supported by the CPACF. See
http://pic.dhe.ibm.com/infocenter/zos/v2r1/topic/com.ibm.zos.v2r1.gsk100/gsk2aa00_Overview_of_hardware_cryptographic_features_and_System_SSL.htm

⁵<http://www-03.ibm.com/support/techdocs/atsmastr.nsf/WebIndex/WP100810>

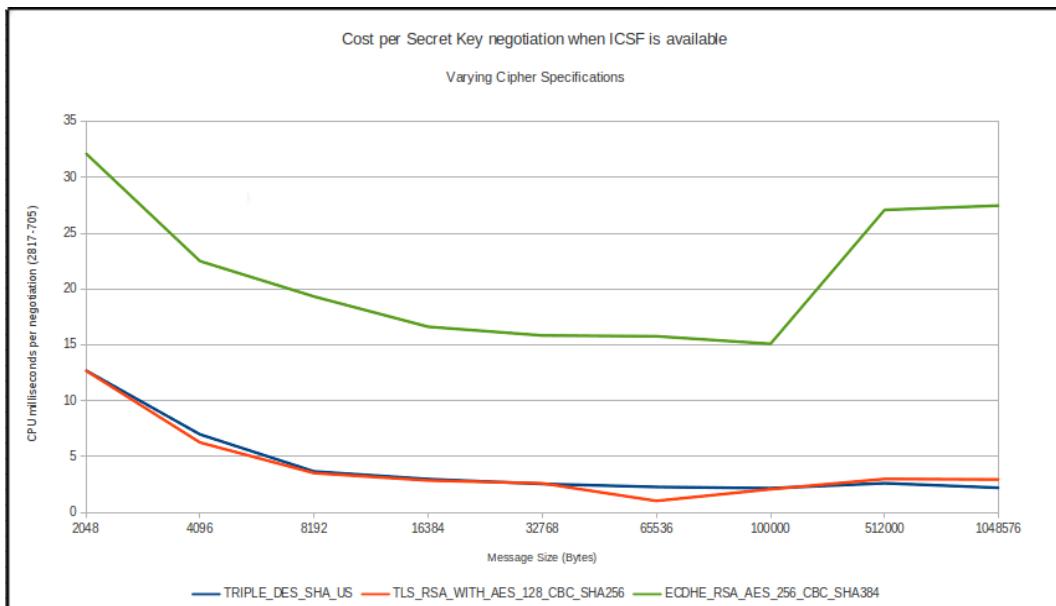
Will using cryptographic co-processors reduce cost?

The cryptographic co-processors are available for offloading the SSL and TLS key renegotiation which occurs at channel start or when the amount of data flowed over the channel reaches the SSLKEYC setting.

In our measurements using the cryptographic co-processors with an SSLKEYC value of 1MB, it was possible to decrease each secret key renegotiation by up to 22 CPU milliseconds depending on message size and cipher specification.

Is the secret key re-negotiation a fixed cost?

In our measurements, the cost of renegotiating the secret key was relatively static over a range of message sizes from 2KB to 1MB.



Note: The cost in the software for negotiating the secret key is significantly higher for the elliptical-type (ECDHE prefixed) cipher specifications but these are more secure.

Whilst some cipher specifications can perform their negotiation in software only, using the cryptographic offload does significantly reduce the cost of the negotiation. For example using TRIPLE DES SHA US costs are typically 2-3 milliseconds per negotiation but if ICSF is unavailable the cost increases to 21 milliseconds.

SHA-2 Algorithm Support for SSL Channels

APAR [PM77341](#) applied to WebSphere MQ for z/OS version 7.1 supports the following new cipherspecs, some of which require specific types of certificates and the enablement of Integrated Cryptographic Service Facility (ICSF):

TLS_RSA_WITH_NULL_SHA256

TLS_RSA_WITH_AES_128_CBC_SHA256

TLS_RSA_WITH_AES_256_CBC_SHA256

ECDHE_ECDSA_AES_128_CBC_SHA256

ECDHE_ECDSA_AES_256_CBC_SHA384

ECDHE_RSA_AES_128_CBC_SHA256

ECDHE_RSA_AES_256_CBC_SHA384

SSL and TLS Costs

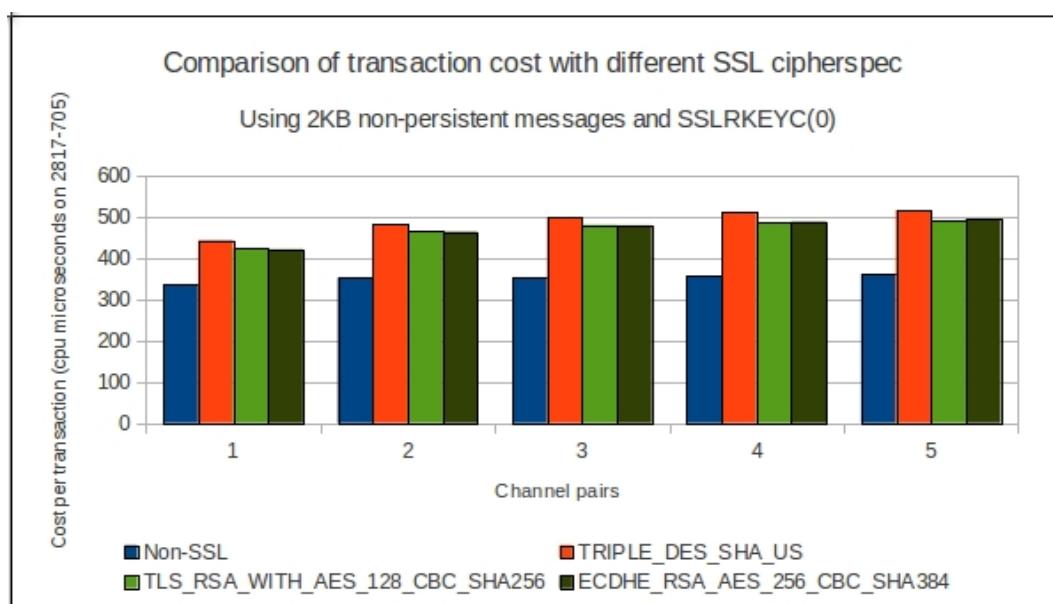
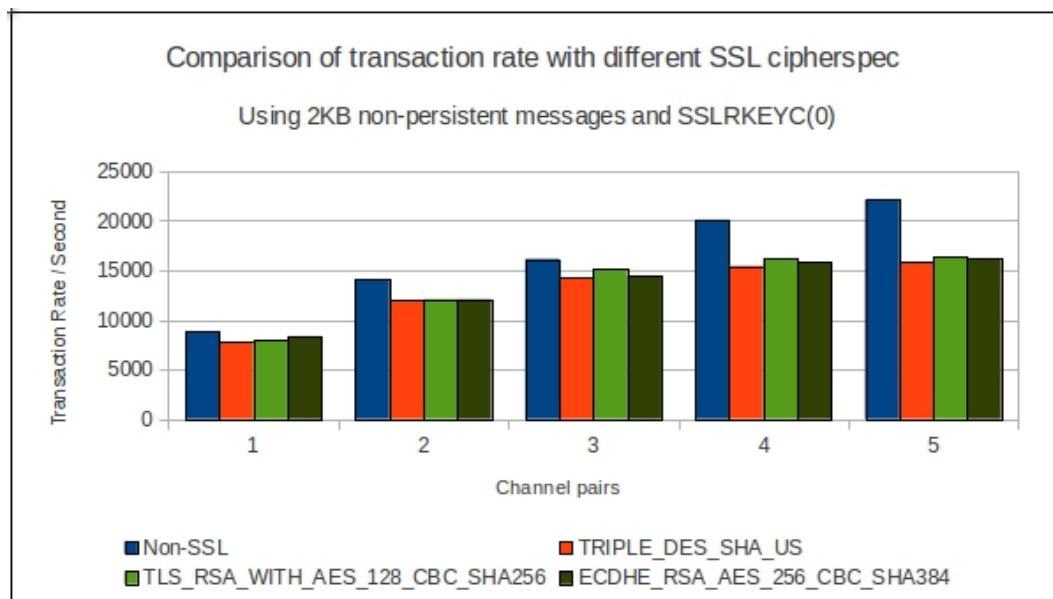
In the previous section, the cost of secret key negotiation was discussed. In order to highlight the costs of data encryption and hashing which is not eligible for offload to the cryptographic coprocessor, the measurements in this section have been run with the SSLRKEYC queue manager attribute set to 0, so that secret key negotiations are not included in the cost.

The data shown in the following charts is from a series of tests run as described:

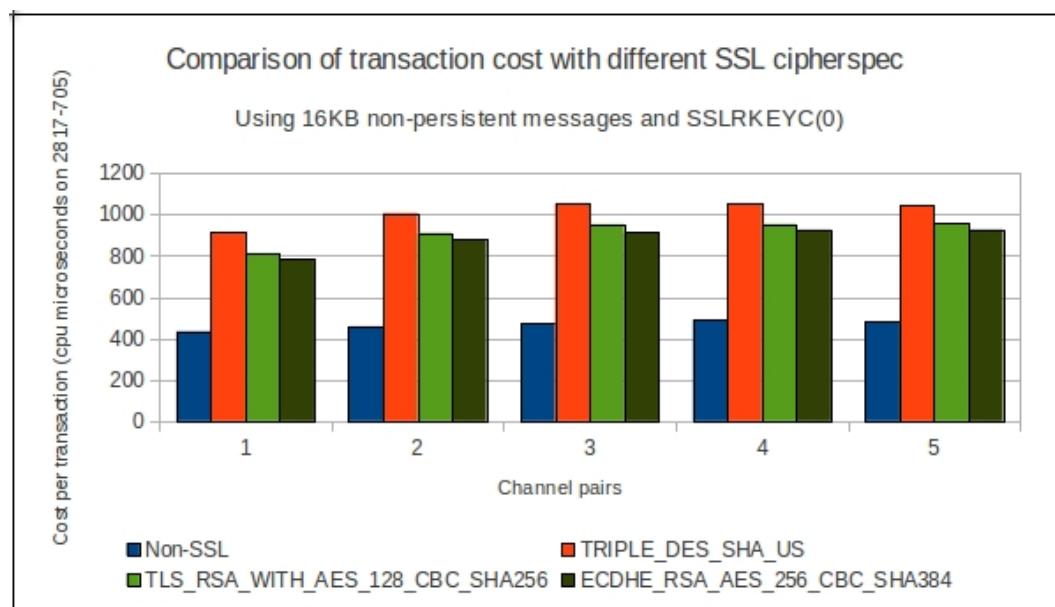
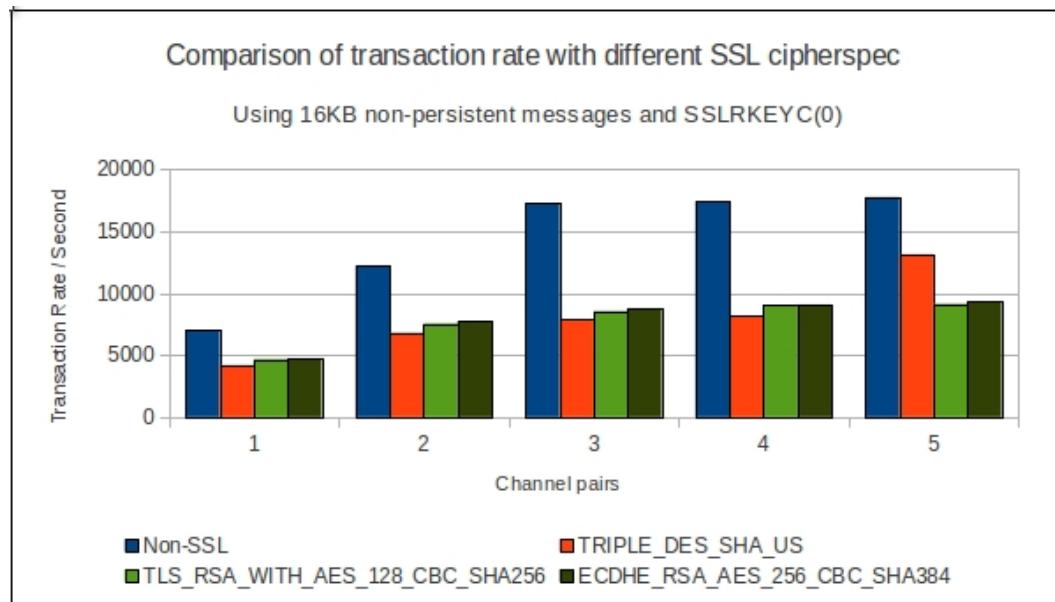
- 2 LPARs running z/OS v1r13 on zEnterprise 196, each configured as 2817-705.
- Each LPAR has 1 queue manager running WebSphere MQ for z/OS version 7.1.0 with PTFs as of 1st February 2013
- The following service applied:
 - HCR77A0 – Cryptographic support for z/OS v1r12-v1r13
 - OA39422 – (System SSL) TLS V1.2 Support
 - PM77341 – (MQ) SHA-2 Algorithm support for SSL Channels
- Each queue manager has 5 in-bound and 5 out-bound sender-receiver channels and the SSL-CIPH attribute is varied between tests for the appropriate cipherspec.
- All channels are started before the measurement runs and remain connected for the lifetime of the test.
- SSLRKEYC is set to 0.
- SSLTASKS is set to 50.
- Messages are non-persistent, to remove logging constraints
- Messages are put in-syncpoint so that variability from “put to waiting getter” is not a factor.
- Channels are defined with DISCINT(0), BATCHSZ(50), NPMSPED(FAST) and BATCHINT(1000).
- On LPAR1, a number of requester tasks will put a message to a remote queue and wait for a response on a corresponding reply-to queue. The get will be by CORRELID. These requesters will repeat this process until told to stop.
- On LPAR2, a number of server tasks will be in a get-with-wait on the request queue, and will put a reply onto the reply-to-queue. The servers will continue until told to stop.
- The test initially uses 10 requesters, 4 servers per channel pair starting from 1 channel pair up to 5 channel pairs. At this point we are seeing network limits reached.
- Costs shown are the total CPU cost for both LPARs including queue manager, channel initiator, TCPIP and application costs.

2KB messages using encrypted channels

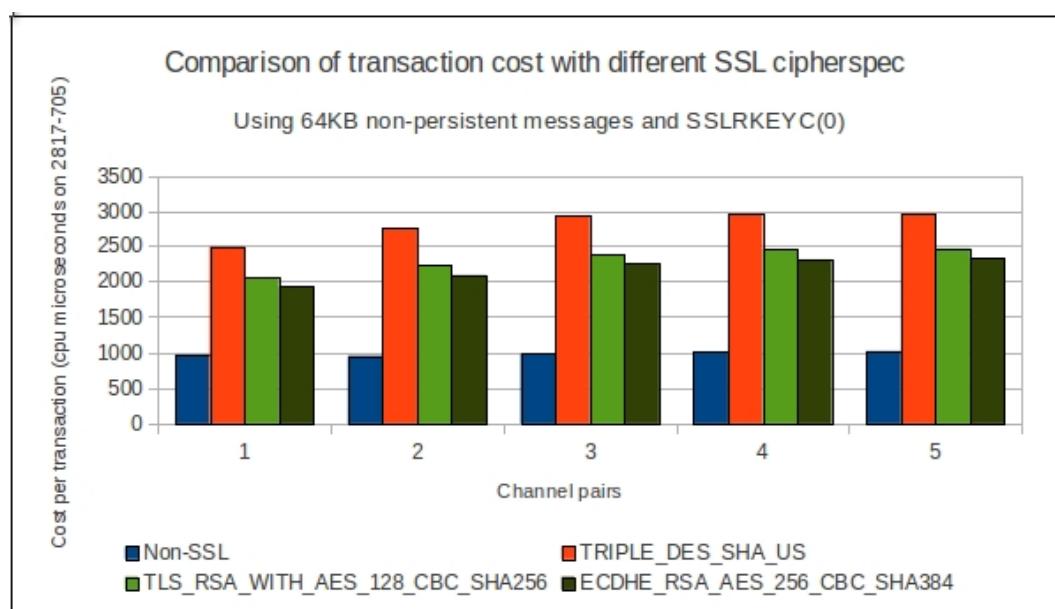
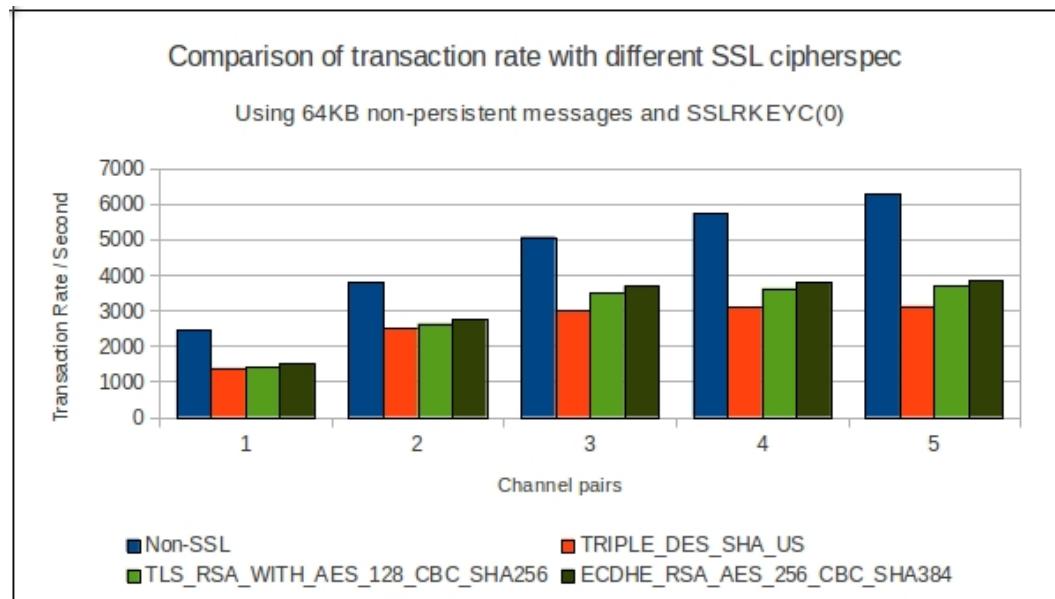
In these measurements, the cost is typically 10% higher on the requester side LPAR. This means that the transaction cost shown for 1 channel with TRIPLE_DES_SHA_US is 442 microseconds, of which 230 microseconds was on the requester and 212 was on the server.



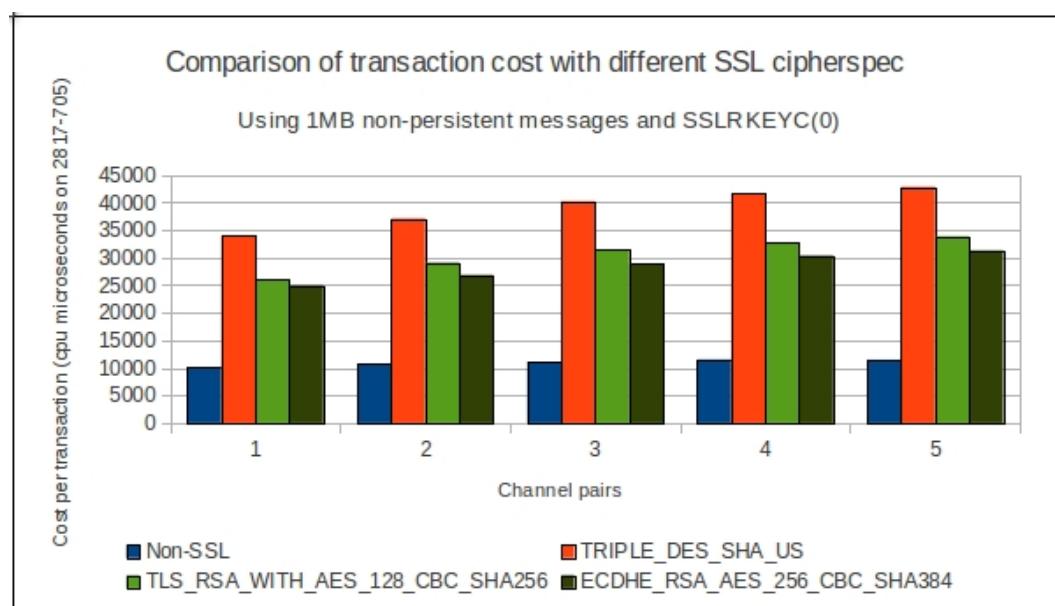
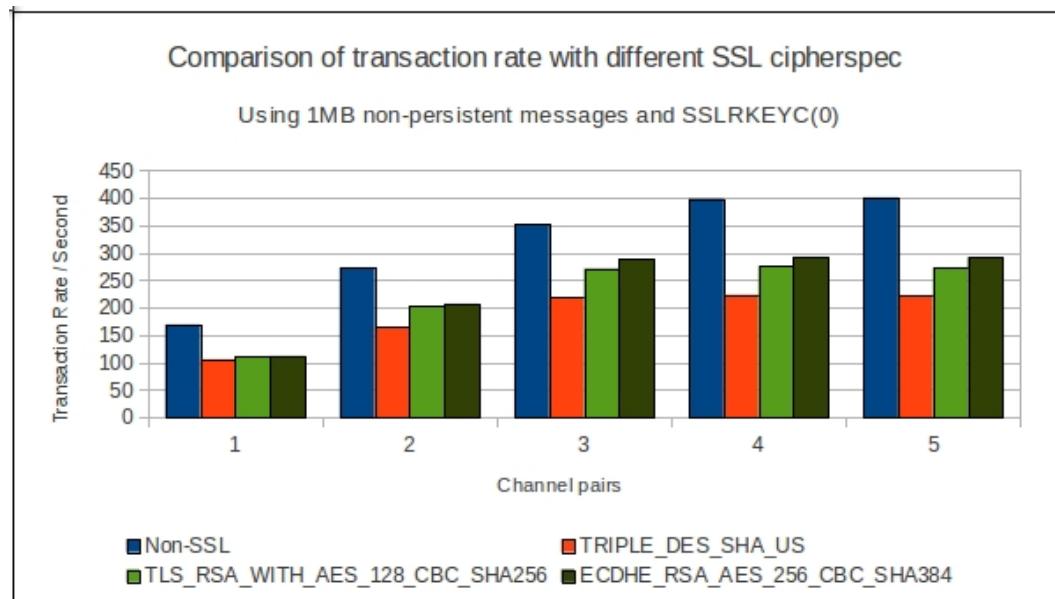
16KB messages using encrypted channels



64KB messages using encrypted channels



1MB messages using encrypted channels



SSL costs – conclusions

The cost per transaction does vary significantly depending on both the cipher specification used and the size of the message.

The previous set of charts show the achieved transactions rates and costs as the number of channels in use increases.

As the costs for data encryption are attributed to the channel initiator, the following table shows the average percent increase in **channel initiator cost per transaction compared to a non-SSL channel** for a range of message sizes.

CipherSpec	2KB	16KB	64KB	1MB
TRIPLE_DES_SHA_US	+57%	+209%	+252%	+347%
TLS_RSA_WITH_AES_256_SHA_CBC	+48%	+157%	+181%	+242%
ECDHE_RSA_AES_256_CBC_SHA384	+45%	+147%	+161%	+222%

According to the table, when using a channel with SSLCIPH “TLS_RSA_WITH_AES_256_SHA_CBC”, a 16KB message transported will cost 157% more in the channel initiator address space than the same message transported over a non-SSL channel.

In our measurements, the total cost of sending a message and receiving a 16KB message over the channels was:

Address space <i>Sender side only</i>	Non-SSL cost in cpu microseconds	SSL using TLS_RSA_WITH AES_256_SHA_CBC (cpu microseconds)	% Change
Queue manager	15	15	0
Channel initiator	121	311	+157%
TCPIP	16	18	+12.5%
Application	75	70	-6.6%
TOTAL	228	414	+81%

The above example shows that whilst the cost of transporting the message over the channel initiator has increased by 157% in the channel initiator address space, the total cost has increased by 81%. In this example, the application is performing a messaging workload and contains no business logic, so if the application costs were 375 microseconds instead of 75, the total increase would have been from 528 to 714, an increase of only 35%.

SSLTASKS

The number of SSLTASKS required depends primarily on the number of channel initiator dispatchers in use. Typically once an SSL server task processes work for a particular dispatcher and all of its channels, there will remain an affinity until restart.

There is also some benefit in ensuring that the number of SSLTASKS is greater than the number of processors in the system.

How many do I need?

This will depend on the number of dispatcher tasks specified in the channel initiator address space, but typically best performance can be achieved with CHIDISPS + 1

Why not have too many?

When a channel starts that requires SSL, the channel initiator will choose the first available SSL task for the initial handshake. For the lifetime of the channel, this same SSL task will be used.

This means that if the channels start at periods when there is no SSL work occurring, it is possible that all of the channels will be using the same small set of SSL tasks. As a result there may be idle SSL tasks in the channel initiator address space.

Each SSL server task uses 1.3MB of storage from the channel initiators available storage, which can impact the number of channels able to be started.

Why not have too few?

If too few SSL server tasks are available, then channel throughput can be constrained as the channels wait for an SSL task to become available.

SSL TASK statistics

With the introduction of Channel Initiator Accounting and Statistics in IBM MQ version 8.0.0, the usage of the SSLTASKS can be reported. This can be used as a guide to whether there are sufficient SSL tasks defined in the channel initiator.

Currently there is no simple mechanism to determine which channel is using a particular SSL task, however the report from program MQSMF⁶ as shown below, does indicate how busy the available SSL tasks are.

If a channel using SSL encryption appears to be performing worse than previously and the SSLTASK report indicates that the SSLTASKS in use are busier than 90%, restarting the channel may move which dispatcher and SSLTASK is used by that channel and result in less waiting for the SSLTASK.

```
MVAA,VTS1,2014/12/20,05:40:27,VRM:900,  
From 2014/12/20,05:39:26.341866 to 2014/12/20,05:40:27.159296 duration 60.817430  
Task,Type,Requests,Busy %, CPU used, CPU %, avg CPU , avg ET  
      ,      ,      ,      , Seconds,      , uSeconds, uSeconds  
0,SSL ,    78284, 26.4, 3.943509,   6.6,      50,     202  
1,SSL ,     37,  0.0, 0.000213,   0.0,       6,       6  
2,...  
8,SSL ,     37,  0.0, 0.000210,   0.0,       6,       5  
9,SSL ,   367304, 27.0, 4.429724,   7.4,      12,     44
```

Note: In the example MQSMF report, there are 10 SSLTASKS available, of which task 0 and 9 are in use and both of these tasks have capacity to support more channels.

SSL channel footprint

Typically SSL uses an additional 30KB for each channel but for messages larger than 32KB can be higher.

SSL over cluster channels?

Using SSL over cluster channels should be no more expensive than SSL over non-cluster channels.

⁶Program MQSMF is available as part of supportPac [MP1B](#)

Note: Repository information being shared will flow over channels and will contribute to the amount of data flowing over a channel and may cause the secret key renegotiation to occur earlier than expected.

Similarly this repository information will be encrypted across the network and will be subject to additional encryption and decryption costs.

SSL over shared channels?

Shared channels will update a DB2 table when their state changes. This can result in shared channels taking longer to start than non-shared channels. No SSL-state information like SSLRKEYS is held in DB2 so using SSL over shared channels will not affect the performance of the channels once the channel is started.

Note: When using shared channels, the channel initiator will check for a certificate named `ibmWebSphereMQ<QSG>` and then `ibmWebSphereMQ<QueueManager>`. This allows the user to use a single certificate for their entire queue sharing group. IBM MQ version 8.0 allows these certificates to be overridden by the certificate named in the CERTABL channel parameter.

Using AT-TLS to encrypt data flowing over IBM MQ channels

Application Transparent Transport Layer Security (AT-TLS) is based on z/OS System SSL, and transparently implements the TLS protocol (defined in RFC 2246) in the TCP layer of the stack.

When running channels between queue managers hosted on z/OS, AT-TLS can be used to encrypt messages transported over MQ channels rather than relying on IBM MQ channels performing the encryption function. The use of AT-TLS can result in reduced costs within MQ.

Who pays for AT-TLS

MQ channels with SSLCIPH configured will see the encryption/decryption cost associated with the channel initiator address space.

When transporting messages using channels encrypted using AT-TLS, the cost of encryption is charged to the callers unit of work (i.e. the channel initiator) and decryption is incurred by the TCPIP address space as the decryption is performed by an SRB running in the TCPIP address space.

Limitations

IBM MQ allows the user to specify different SSL cipher specifications for each channel.

To run with different cipher specifications using AT-TLS can involve defining additional rules plus either specifying the LOCLADDR attribute on the channel to restrict the port being used or by running with multiple listeners defined on the channel initiator.

IBM MQ allows the secret key negotiation to be performed when the number of bytes sent and received within an SSL conversation exceeds the SSLRKEYC value, whereas AT-TLS allows the renegotiation to take place after a period of time has been exceeded.

When the AT-TLS encryption is performed, the TCP socket is blocked – this can have a noticeable effect on throughput rate with large messages unless dynamic right sizing is enabled on the TCPIP stack.

Channels protected with CHLAUTH rules may not be allowed to start if the rule contains a value for SSLPEER.

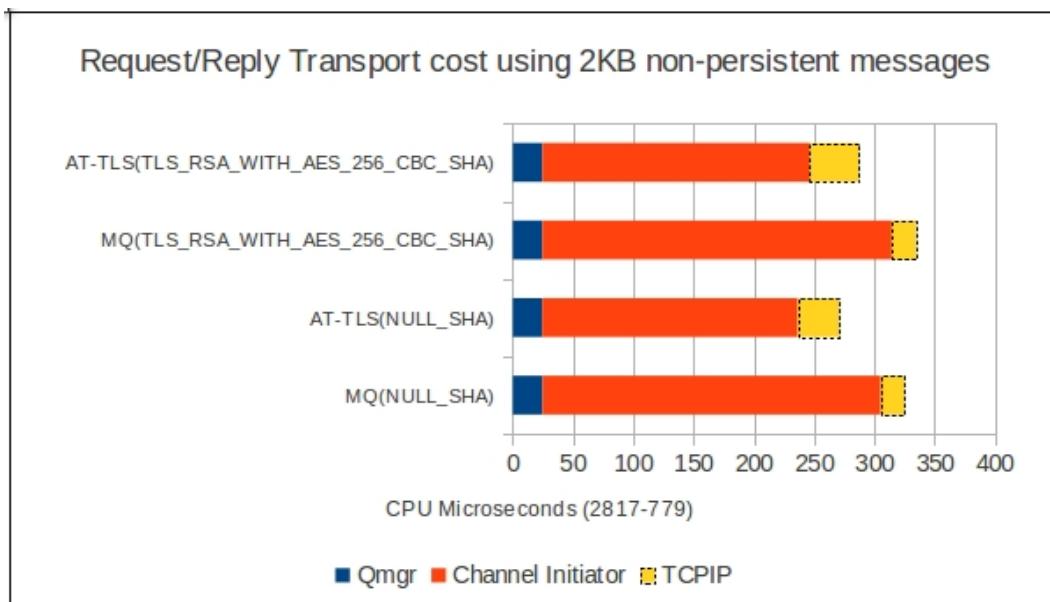
Performance comparison

The following measurements were run using a 10Gb network between 2 z/OS v1r13 LPARs each with 5 dedicated processors on a 2817-779.

A request/reply workload between 2 queue managers was run over a pair of sender-receiver channels using non-persistent messages.

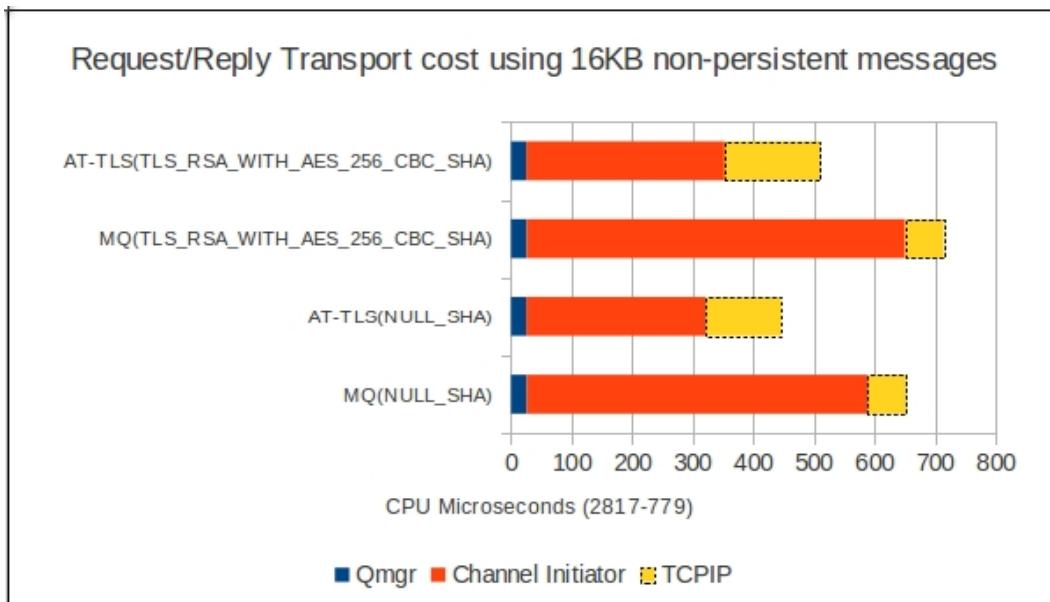
In the measurements using channels with SSLCIPH cipher specifications, the SSL key negotiation has been disabled (by setting to '0') in order to provide a direct comparison. Similarly the AT-TLS negotiation period has been disabled.

The costs shown in the following charts are for the queue manager, channel initiator and TCPIP address spaces only and are based on the cost observed in both LPARs.



Notes on preceding chart:

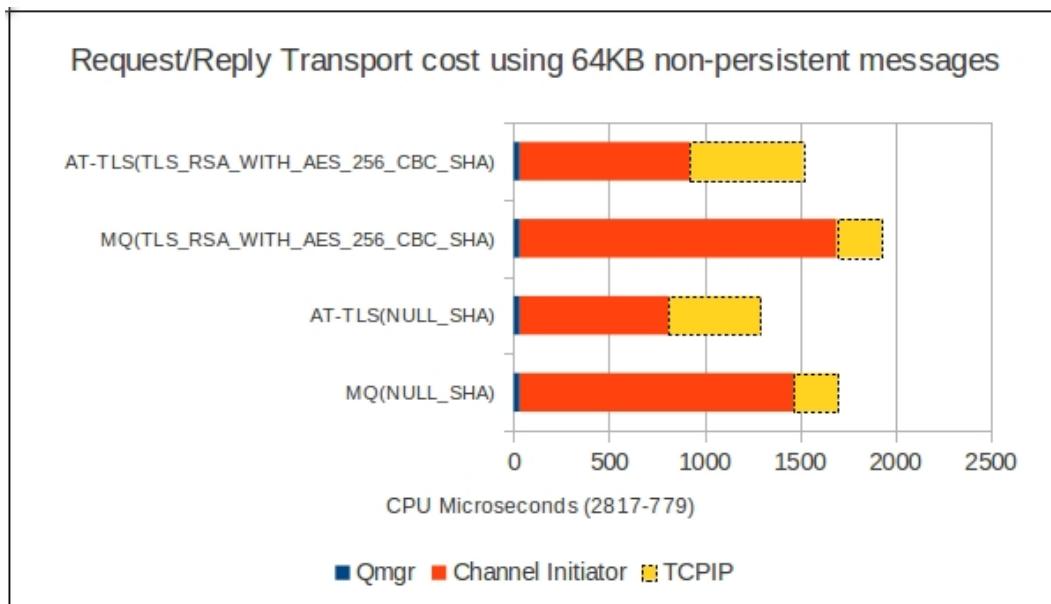
- The queue manager cost is not affected by the level of encryption nor by who performs the encryption.
- The total cost of transporting the message is 15% less when using AT-TLS
- The channel initiator costs are 24% lower when using AT-TLS
- TCPIP costs double when using AT-TLS.



Notes on preceding chart:

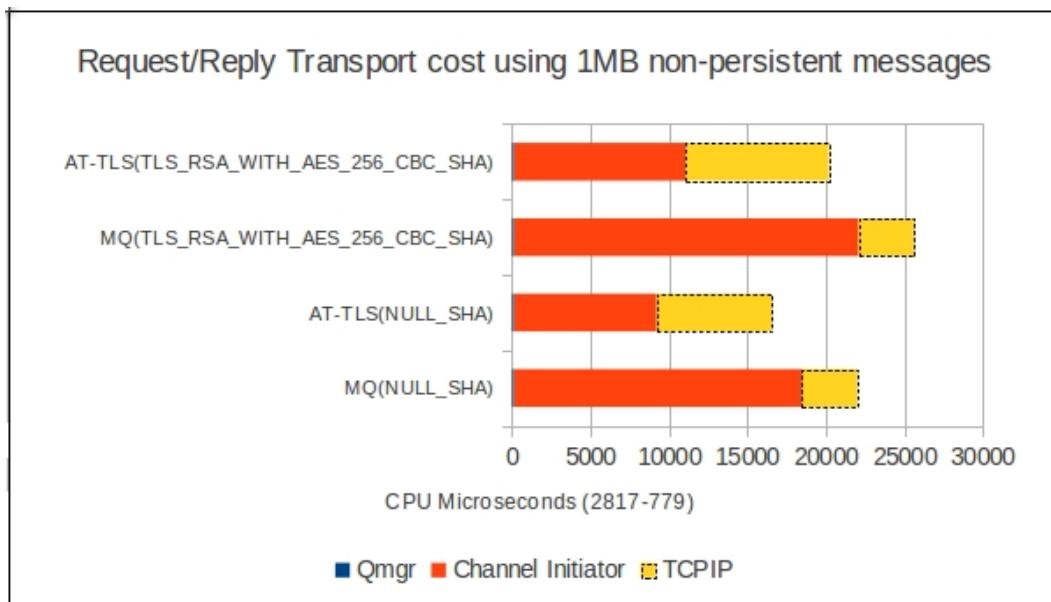
- The total cost of transporting the message is 30% less when using AT-TLS
- The channel initiator costs are 45% lower when using AT-TLS

- TCPIP costs are double using NULL_SHA and approximately 2.5 times using TLS_RSA_WITH_AES_256_CBC_SHA.



Notes on preceding chart:

- The total cost of transporting the message is 24% less when using AT-TLS
- The channel initiator costs are 45% lower when using AT-TLS
- TCPIP costs are double using NULL_SHA and approximately 2.5 times using TLS_RSA_WITH_AES_256_CBC_SHA.



Notes on preceding chart:

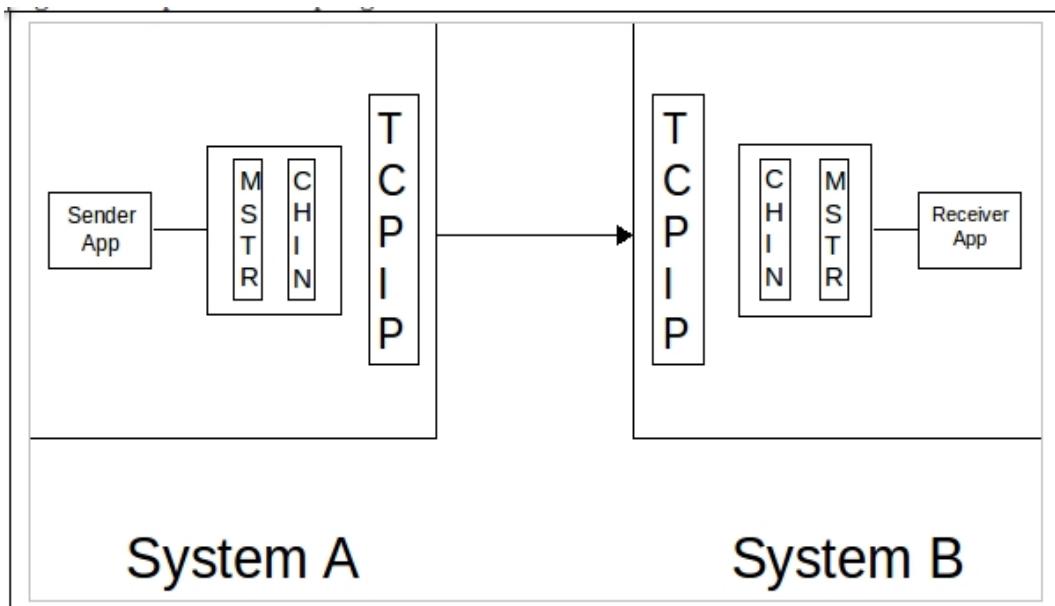
- The total cost of transporting the message is 24% less when using AT-TLS

- The channel initiator costs are 50% lower when using AT-TLS
- TCPIP costs are double using NULL_SHA and approximately 2.5 times using TLS_RSA_WITH_AES_256_CBC_SHA.

Costs of Moving Messages To and From MVS Images

This section considers the total CPU costs of moving messages between queue managers in separate MVS images. A driver application attached to a queue manager in System A puts a message to a remote queue which is defined on a queue manager running in System B. A server application in System B retrieves any messages which arrive on the local queue.

No code page conversion costs are included in any “MVS to MVS” measurements. See “[How much extra does code page conversion cost on an MQGET?](#)” for an estimate of typical MQFMT_STRING code page conversion costs.



Notes on diagram:

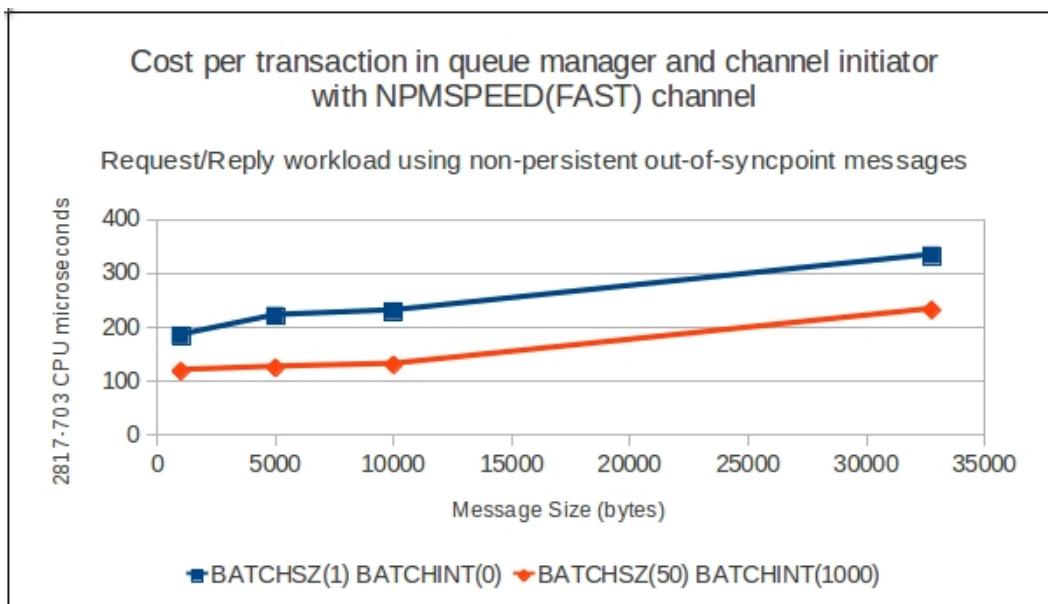
- Each MVS image was a 3-CPU logical partition (LPAR) of a zEnterprise 196.
- The MVS systems were connected via a 1Gb Ethernet network.
- The driver application continually loops, putting messages to the remote queue.
- The server application continually loops, using get-with-wait to retrieve the messages.
- Neither application involves any business logic.
- The server application runs non-swappable.
- The queue is not indexed.
- All non-persistent messages were put out of syncpoint by the sender application. and got out of syncpoint by the server application.

Measurements were made with two different channel settings:

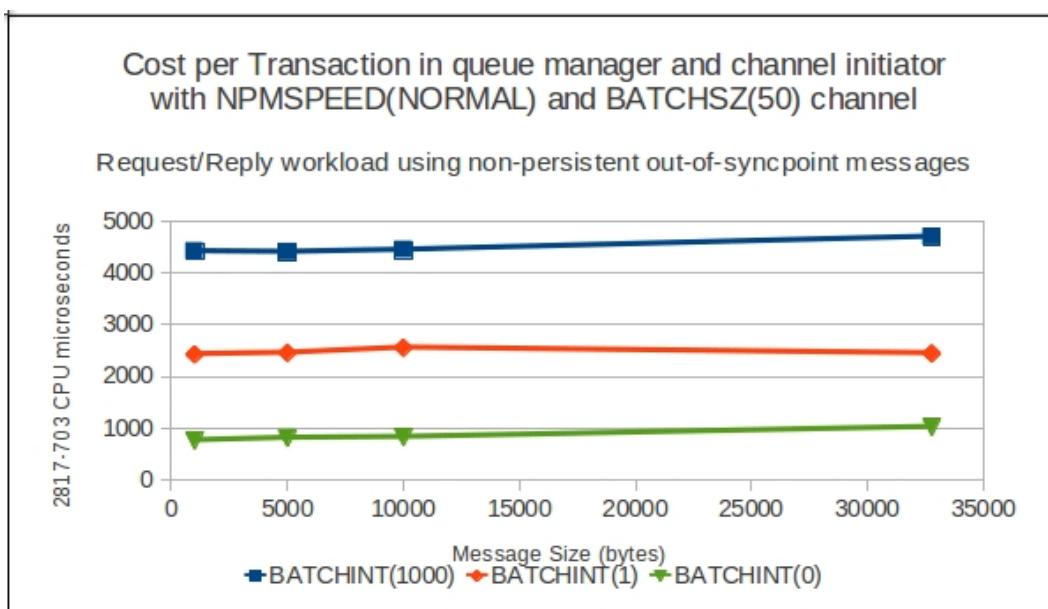
- BATCHSZ(1) with BATCHINT(0) and NPMSPED(FAST)
- BATCHSZ(50) with BATCHINT(1000) and NPMSPED(FAST)

The chart below show the CPU costs in both systems for non-persistent messages with a variety of message sizes for the queue manager and channel initiator address spaces.

NOTE: In the following 2 charts, there is only 1 requester and 1 server application, but by setting the BATCHINT to 1000 to keep the batch open for longer, the cost is significantly reduced.



Contrast the previous chart with the following that shows using a channel with NPMSPEED(NORMAL). With NPMSPEED(NORMAL) the effects of holding the batch open with BATCHINT and the cost of channel syncpoints becomes clear.



NOTE: With NPMSPEED(NORMAL), the achieved batch size was 1, but varying the BATCHINT to 0 made a significant difference to the transaction rate. For example:

- With 1 requester and a BATCHINT(1000), only 1 message per second is flowing over the sender channel.
- With NPMSPEED(NORMAL) and BATCHINT(0), the rate increased to 800 messages per second.

Non-persistent messages

For **BATCHSZ(1)** the CPU usage is approximately:

The total (sender and receiver queue manager and channel initiator) cost:

$(187 + 4.4S)$ CPU microseconds per message,
where S is the size of the message expressed in 1000's of bytes.

The costs are shared evenly between the sender and receiver end.
E.g. for a 10,000 byte message this is:

$(187 + 4.4 \cdot 10) = 231$ CPU microseconds - approximately 115 at the sender end and at the receiver end.

For **BATCHSZ(50)** the CPU usage is approximately:

The total (sender and receiver queue manager and channel initiator) cost:

$(105 + 3.7S)$ CPU microseconds per message
where S is the size of the message expressed in 1000's of bytes

E.g. for a 10,000 byte message this is:

$(105 + 3.7 \cdot 10) = 138$ CPU microseconds - approximately 69 CPU microseconds at the sender and also at the receiver end.

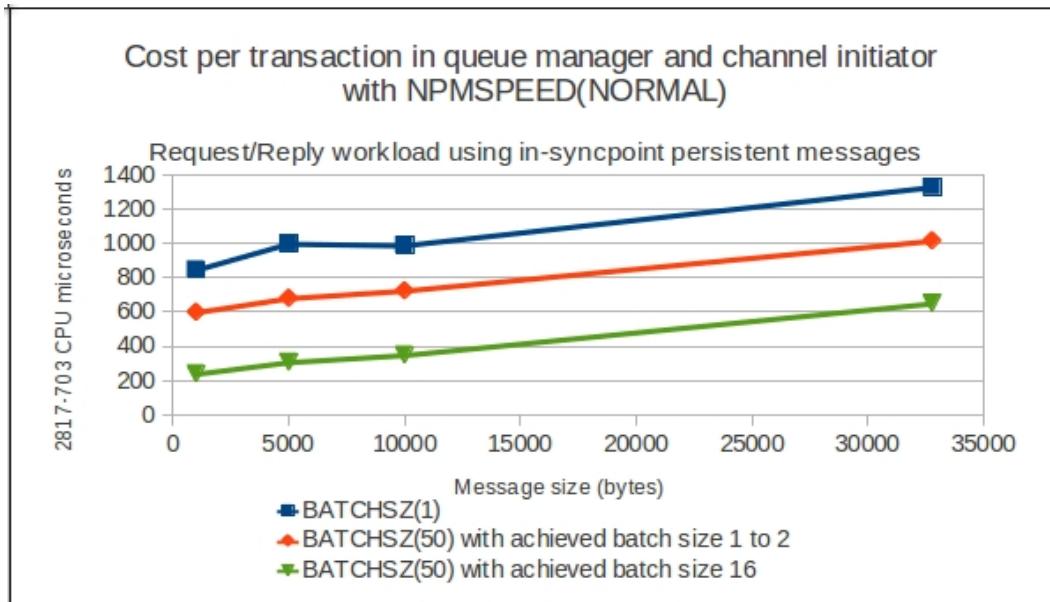
These algorithms produce figures which are within 10% of the measured figure for the range shown in the charts.

Persistent messages

All persistent messages were put within syncpoint by the sender application and got within syncpoint by the server application. Measurements were made with three different configurations all using NPMSPEED(NORMAL):

- BATCHSZ(1)
- BATCHSZ(50) with achieved batch size of 1 to 2.
- BATCHSZ(50) with achieved batch size of 16.

The chart below show the total CPU usage in both systems for persistent messages with a variety of message sizes.



A reduction in the CPU usage at both ends of the transaction when conditions allow a batch size greater than 1 can be achieved. A slow rate of MQPUT with BATCHSZ(50) will see the achieved batch rate drop to 1 and the associated cost per transaction increase to parity with BATCHSZ(1). Reducing the number of batches results in a reduction in the number of channel synchronisations and TCPIP transactions per message.

Note: That this reduction in CPU is dependent upon messages being put at a suitable rate. In a more realistic situation where the achieved batch size is close to 1, the CPU usage increases, as shown by the top line in the chart.

The lowest CPU costs are achieved when the application unit of work exactly matches the channel BATCHSZ parameter.

For capacity planning purposes it is safest to assume BATCHSZ(1) will be used. If it is known that a higher batch size can consistently be achieved, a higher figure may be used.

An approximate straight line algorithm is presented here for the CPU usage with **BATCHSZ(1)**:

The total (sender and receiver queue manager and channel initiator) cost:

(870 + 14S) CPU microseconds per message
where S is the size of the message expressed in 1000's of bytes

e.g. for a 10,000 byte message this is:

(870 + 14*10) = 1010 CPU microseconds – with approximately 500 at the sender end and 500 at the receiver end.

This represents the ‘best choice scenario’ for persistent messages where the achieved batch size is undetermined.

This algorithm produces figures which are within 10% of the measured figure for the range shown in the charts.

Chapter 4

System

Hardware

DASD

There are limits to persistent message rates achievable

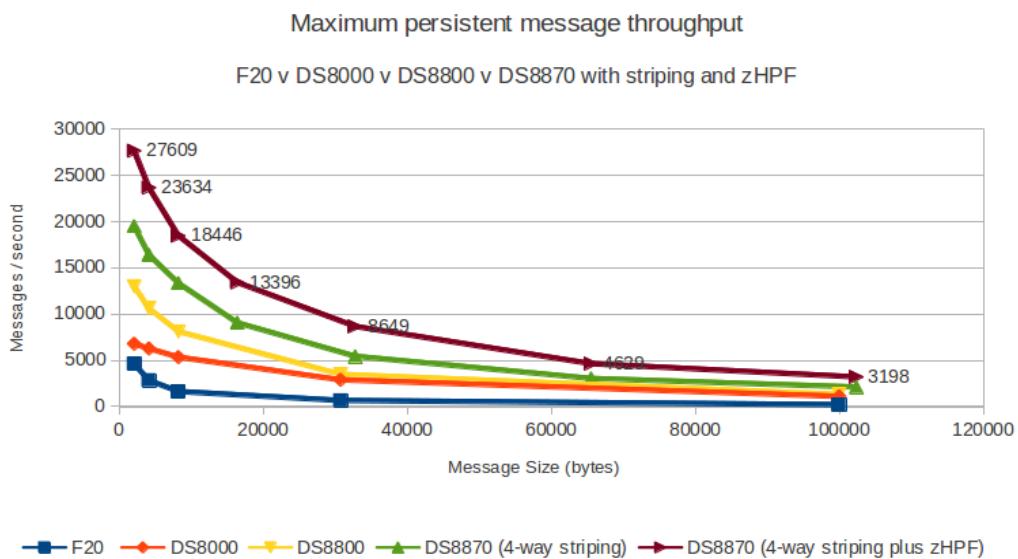
- Because of upper bounds to the overall data rate to a IBM MQ log, see “[Upper bound on persistent message capacity - DASD log data rate](#)” to overcome any such limit then either faster DASD or more queue managers will be required.
- Because of upper bounds to the log I/O rate achievable by a single application instance, which may be required where messages must be processed in strict order.
- There is a limit to the maximum number of messages through one queue, see [Maximum throughput using non-persistent messages](#).

Maximum request/reply throughput (DS8870)

The following chart shows the maximum throughput we could achieve with many request and reply applications for a range of message sizes. Sufficient processors were available so they were not a limiting factor in the throughput capacity.

Performance data from DS8000 and F20 (RAID5 configured) DASD is included for comparison purposes, however the measurements are not directly comparable as they span different levels of IBM MQ and System Z hardware.

As can be seen in the following chart, the underlying disk technology can make a significant difference in the rate that MQ is able to log messages.



Upper bound on persistent message capacity - DASD log data rate

The maximum total IBM MQ system capacity for persistent messages is bounded by the maximum data rate sustainable to the DASD subsystem where the IBM MQ logs reside. For IBM MQ with dual logging, the maximum sustainable data rate **for messages put at one message per commit and got at one message per commit** is about:

Log data set DASD type	1KB messages	5KB messages	1 MB messages
RVA-T82	2.3 MB/sec	2.8MB/sec	
ESS E20 with ESCON	5.3 MB/sec	7.1 MB/sec	
ESS F20 with ESCON	7.1 MB/sec	10.2 MB/sec	11.3 MB/sec
ESS F20 with FICON	7.4 MB/sec	13.0 MB/sec	15.6 MB/sec
ESS 800	10.0 MB/sec	16.5 MB/sec	24 MB/sec
DS8000 (RAID 5)	14.9 MB/sec	36.0 MB/sec	68.1 MB/sec
DS8000 (RAID 10)	15.6 MB/sec	36.1 MB/sec	68.6 MB/sec
DS8800 (RAID5)	32.1 MB/sec	62.4 MB/sec	128.7MB/sec
DS8870 (RAID 5) with 4-stripes	47.8 MB/sec	98.5 MB/sec	215 MB/sec
DS8870 (RAID 5) with 4 stripes plus zHPF enabled	64.7 MB/sec	136.4 MB/sec	337.5 MB/sec

These are the peak rates on our system configuration. It is usually prudent to plan not to exceed 50% of the rates attainable on the target system particularly where message response time and not just overall message throughput is important.

What is the effect of dual versus single logging on throughput?

On our system use of single logging rather than dual logging increased throughput by about 5%. On a system with significant DASD constraint use of single logging might enable a much more significant throughput increase. Use of single logging would mean there is a single point of failure possibility in your system.

Will striped logs improve performance?

Switching to active logs which use VSAM striping can lead to improved throughput in situations where performance is being constrained by the log data rate. The benefit obtained from using VSAM striping varies according to the amount of data being written to the log on each write. For example, if the log dataset has been set up with 4 stripes, a log write carrying a small amount of data such that only one stripe is accessed will gain no benefit at all, while a log write carrying sufficient data to access all 4 stripes will gain the maximum benefit.

The increased logging rate achieved by using striped active logs will result in the log filling more quickly. Prior to IBM MQ version 8.0.0 however, the time taken to archive a log dataset is unchanged. This is because archive log datasets must not be striped as the BDAM backwards reads required during recovery are not supported on striped datasets. Thus the possibility of needing to reuse a log dataset before its previous archive has completed is increased. It may therefore be necessary to increase the number or size of active log datasets when striping is used. **If you attempt to sustain these maximum rates to striped logs for long enough then eventually you will fill all your active logs with consequent unacceptable performance.**

Version 8.0.0 saw the changing of archive datasets from BDAM to QSAM, which allows the allocation to exceed 65,535 tracks and the striping of the archive logs. Striping of the archive logs may result in an improved rate of offload. We did see an increase in cost in the queue manager address space when using archive datasets larger than 65,535 tracks when the dataset is using extended format.

In summary, striped logs are most likely to be of use where there is a reasonably predictable amount of large messages in a particular time period such that the total amount of data to be logged does not cause the active logs to be filled.

Will striped logs affect the time taken to restart after a failure?

The recovery process will need to read active logs and this is significantly quicker with striped datasets, particularly for the backward recovery phase. It may also involve reading archived log datasets that cannot be striped. Thus any use of archive log datasets during recovery will not be quicker. It is possible to minimise or even eliminate the possibility of an archive log being required during recovery. This requires pageset and if using shared queue, CF structure backup, at appropriate intervals and appropriate reaction to any CSQJ160I messages concerning long running units of recovery with a STARTRBA no longer in active logs. With version 6, implementation of log shunting, archive log datasets will not be used for recovery unless pageset or CF structure media recovery is required.

Benefits of using zHPF with IBM MQ

What is zHPF?

High Performance FICON for System z (zHPF) is a data transfer protocol that is optionally employed for accessing data from IBM DS8000 storage and other subsystems and was made available for System z in October 2008.

zHPF may help reduce the infrastructure costs for System z I/O by efficiently utilizing I/O resources so that fewer CHPIDs, fibers, switch ports and control units are required.

The following link gives a more detailed overview of what is zHPF and how it can benefit a z10 (and subsequent System Z hardware) user:

- <http://www-03.ibm.com/support/techdocs/atstrmstr.nsf/WebIndex/WP102468>

When can it help with IBM MQ work?

zHPF is concerned with I/O to DASD, so queue managers that are used for non-persistent workload may see little benefit.

Similarly, where the LPAR is running with low volume I/O, it is unlikely that using zHPF will give much benefit.

Where multiple queue managers exist on the same LPAR and are processing high volume persistent workload, whether local or shared queue, zHPF may be able to provide an increase in the throughput rate.

- Where throughput was restricted by the number of I/O channels available and then zHPF was enabled, we saw a doubling of throughput.
- Where throughput was restricted by the DASD logging rate, enabling zHPF saw a 17% increase in transaction rate.
- With larger messages (1MB and larger) using zHPF and striped logs, throughput was increased by 55%.

For a more detailed summary of the investigation into the benefits of zHPF with regards to IBM MQ, please refer to:

- <http://www-01.ibm.com/support/docview.wss?uid=swg27015698>

Network

The measurements run in this document have been typically run on our dedicated performance network which is rated at 1Gb.

When we moved onto a dedicated 10Gb performance network, we saw a number of changes:

- Measurements were more consistent.
- Response times for measurements with low numbers of channels were slightly faster than when run on the slower network.
- CPU became the constraint point rather than network.
- Dedicated CHPIDs on LPARs that perform high volume network traffic gave significantly better performance than shared CHPIDs – even when RMF shows CHPID is not at capacity.

By moving onto a more modern network with greater capacity we haven't greatly improved a single channels peak transmission rate, but we have been able to increase the number of channels driving data to exploit the additional band-width.

Our network is high-bandwidth low-latency which means we can expect good response times for request/reply type workloads.

It is important to consider what sort of network you have and tune your channels accordingly.

For example, a high-bandwidth high-latency network would not be ideal for a request-reply type workload. It would be more suited to sending large batches of data before waiting for acknowledgement, perhaps looking at batch size and batch intervals to keep the batch open for longer. In addition, if work can be spread across multiple channels to exploit the high-bandwidth this may help.

On a low-bandwidth high-latency network, it might be appropriate to consider message compression, but there will be a trade-off with increased CPU costs which vary with compression algorithm. The usage of zEDC with channel compression type ZLIBFAST may reduce the compression costs.

IBM MQ and zEnterprise Data Compression (zEDC)

IBM® zEnterprise® Data Compression (zEDC) capability and Peripheral Component Interconnect Express (PCIe or PCI Express) hardware adapter called *zEDC Express* were announced in July 2013 as enhancements to the IBM z/OS® V2.1 operating system and the IBM zEnterprise EC12 (zEC12) and the IBM zEnterprise BC12 (zBC12).

zEDC is optimised for use with large sequential files, and uses an industry-standard compression library. zEDC can help improve disk usage and optimize cross-platform exchange of data with minimal effect on processor usage.

There are a number of uses for zEDC which may affect the performance of the IBM MQ product including:

- Channel compression using ZLIBFAST. The performance benefits are discussed in [MP1J](#) “IBM MQ for z/OS version 8.0.0 Performance Report”.
- [Compressing archive logs](#) to reduce storage occupancy.
- [IBM MQ and zEDC with SMF](#), which discusses the impact of capturing accounting data in a high volume, short-lived transaction environment.

Reducing storage occupancy with zEDC

Can I use zEDC with MQ data sets?

Sequential files allocated by using basic sequential access method (BSAM) or queue sequential access method (QSAM) can be compressed using the IBM zEnterprise Data Compression Express (zEDC Express) feature.

In an MQ subsystem, this means that archive data sets are eligible for compression.

What benefits might I see?

There are a number of benefits which using zEDC to compress MQ archive logs may bring:

- **Reduced storage occupancy of archive volumes**, meaning more archives can be stored on the same number of 3390 volumes. The compressibility of the messages logged will be the largest factor in the archive data set size reduction.
- **Reduced load on the IO subsystem**, which in a constrained subsystem could improve response rate on other volumes.

In our tests with dual logs and dual archives where the IO subsystems' cache was seeing increased disk fast write bypass (DFWBP) on the control unit used by both log copy 2 and the archive volumes, enabling archive log compression resulted in the response times from the I/O to log copy 2 reducing, with DFWBP being 0, which manifested in a 45% improvement in peak throughput with large messages.

What impact might I see?

The process of compressing, or indeed attempting to compress the MQ archive logs will result in an increase in queue manager TCB costs. For a queue manager running a dedicated persistent workload with the intent to drive the MQ log process to its limit for a range of message sizes, we observed the queue manager TCB cost increase for the zEDC enabled measurements.

The following table is a guide to how much the queue manager TCB cost increased:

Message Size	4KB	32KB	1MB	4MB
Increase in QM TCB over non-zEDC measurement	+7%	+26%	+90%	+100%
Increase in peak throughput	1%	2%	30%	45%

Note: Some of the increase in queue manager TCB is associated with the increased peak log rate, but there is some additional cost on MVS from the allocation/releasing of the target compression buffer plus some costs in setting up the call to the zEDC hardware.

Reading the MQ archive data sets, such as when the “RECOVER CFSTRUCT” command was issued, was impacted when the archives were compressed using zEDC. This impact took the form of both a **reduced read rate** coupled with an increase in queue manager TCB costs for decompressing the data.

The following table summarises the results of a “RECOVER CFSTRUCT” command resulting in the recovery of 4GB of data.

	Uncompressed Archives	Archives compressed using zEDC
Recovery Rate (MB/sec)	88	27
Cost per MB (CPU ms)	860	1900

The numbers in the table are based upon a MQ V9.0 queue manager with 4GB of data stored on shared queues with data offloaded to SMDS. For the purposes of the backup and recovery tests, the queue manager is configured with single logs and single archives. The data on the queues is highly compressible. The costs are based on the measurements running on an LPAR with 3 dedicated processors of a 2964-7E1 (z13).

When MQ is writing archive logs at a high rate the RMF PCIE report indicated that the single configured zEDC processor for the logical partition was running up to 65% utilised when compressing the dual archive logs for a single MQ queue manager. This peak usage occurred when the message was incompressible. With highly compressible messages at the peak logging rate, the zEDC processor was 50% utilised.

The PCIe I/O drawer in which the zEDC Express feature can be installed, can support up to 8 features with each feature able to be shared across 16 logical partitions. Sufficient zEDC features should be available to avoid impacting other users of the feature.

How we set up for testing

For the initial configuration we used Redbook “[Reduce Storage Occupancy and Increase Operations Efficiency with IBM zEnterprise Data Compression](#)”. Within this document, sections 4.2 to 4.5 were of particular interest as they discuss DB2 log archive data sets.

For our testing purposes, we already had a storage group for the MQ archive data sets, so we defined a dataclass of ZEDC, specifying ZR (zEDC required) for compaction and the data set name type of EXTENDED.

We also defined a storage group MQZEDC that was based on the existing MQMARCH storage group and added a similar number of volumes to the group.

Note, the zEDC feature was already enabled on the test system.

What to watch out for

The initial set up did not specify a value of EXTENDED for the data set name type - as a result measurements showed similar size archive and log data sets - indicating the data was incompressible or that no compression was attempted.

A subsequent review of the PCIE XML report produced by program ERBRMFPP indicated the zEDC processor was not being used.

The PCIE report can be generated by specifying “REPORTS(PCIE)” and viewing the contents of the XRPTS DD card, which contains data generated in XML format.

Measurements

On our performance system, measurements were run using a range of message sizes from 2KB to 4MB.

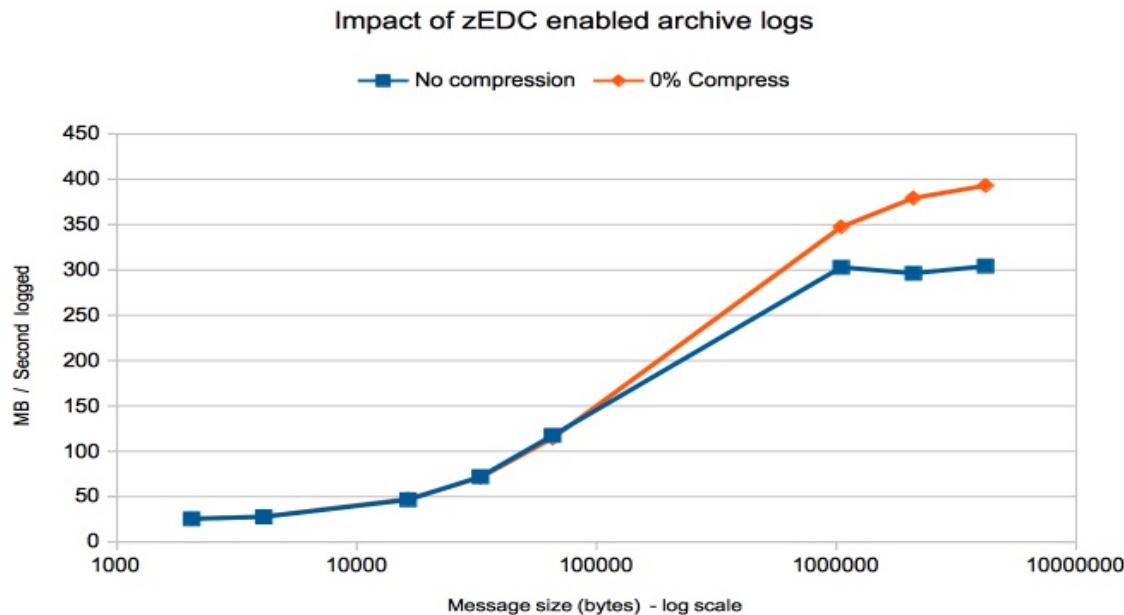
The queue manager was configured with dual logs and dual archives. There were sufficient logs available such that a slow archive would not delay log reuse.

Measurements were run on an LPAR with 3 dedicated processors on a 2964-7E1 with a dedicated DS8870 with FICON Express 16S links.

The I/O subsystem was configured such that log copy 1 used control unit 7004, and log copy 2 plus the archive logs used control unit 7128.

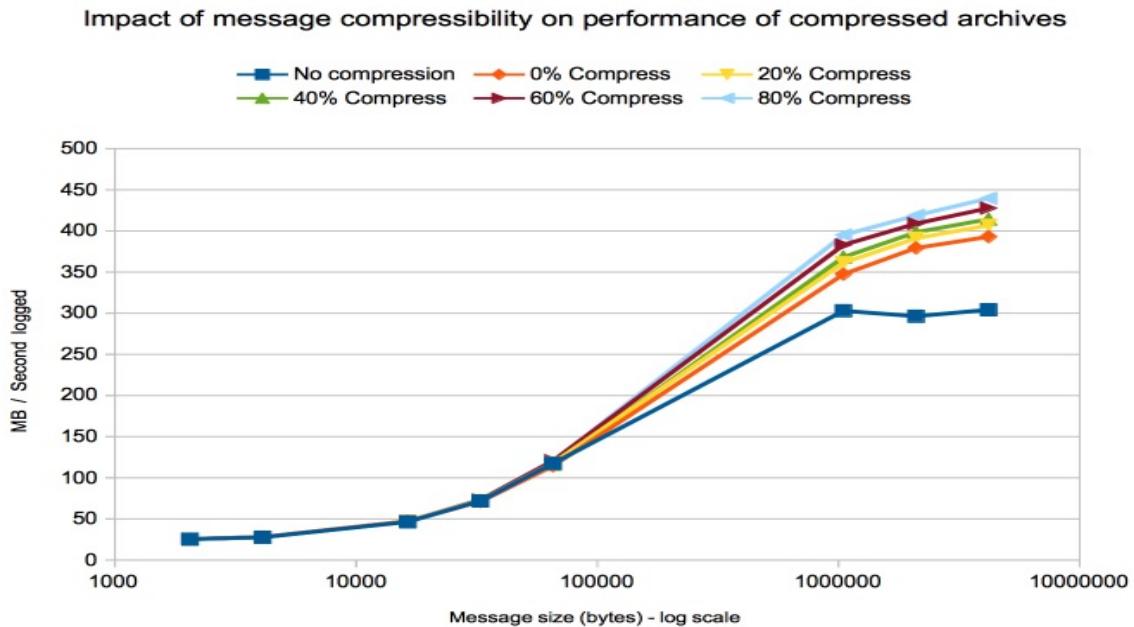
The following chart demonstrate the maximum sustained log rate where the data is minimally compressible.

In these measurements, an increase in log rate was observed when archive log compression was available for messages larger than 64KB, with a **30% improvement** in log rate with 4MB messages. *Given the data is uncompressible, this may be a side effect of moving to the EXTENDED archive data sets. Extended archive data sets have been supported since MQ version 8.0.*



How compressible is the data?

The following chart demonstrates the increase in log rate as the data becomes more compressible:



Highly compressible large messages benefit more from being compressed, and in our measurements where 4MB messages could be compressed by 80%, the **log rate increased by 45%**, to 440MB/second, compared to non-compressed archives.

Whether the I/O subsystem is constrained

As the data logged becomes more compressible, the amount of data written reduces, putting less load on the I/O subsystem.

With our configuration of the archive data sets using the same control unit as log copy 2, the MQ SMF data showed:

-----,-- write requests,	CIIs,	Average I/O ,	After I/O ,	pages/I/O	
		time in uSec,	time in uSec,		
Log 1, 1 page	4273,	4273,	192,	5,	1
Log 1,>1 page	43776,	4520380,	766,	2,	1e+02
Log 2, 1 page	4273,	4273,	243,	20,	1
Log 2,>1 page	43776,	4520380,	1218,	35,	1e+02

Note the difference in average I/O time between log copy 1 and log copy 2, particularly when writing multiple pages.

We can also see from the Cache Subsystem Report that control unit 7128 shows signs of disk fast write bypass (DFWBP).

SSID	CU-ID	TYPE	CACHE	NVS	I/O	OFF	--CACHE HIT RATE--				-----DASD I/O RATE-----				
							RATE	RATE	READ	DFW	CFW	STAGE	DFWBP	ICL	BYP
2100	7004	2107-961	507G	16G	7468	0.0	4296	3172	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2101	7128	2107-961	507G	16G	8995	0.0	520.9	8474	0.0	0.0	2727	0.0	0.0	0.0	0.0
2102	7407	2107-961	507G	16G	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

By contrast the equivalent measurement from the 0% compressible measurement shows no DFWBP on either control unit and the MQ SMF data shows:

____,-- write requests,	CIs, Average I/O , After I/O , pages/I/O time in uSec, time in uSec,
Log 1, 1 page	5273, 5273, 201, 5, 1
Log 1,>1 page	58617, 6057227, 811, 2, 1e+02
Log 2, 1 page	5273, 5273, 183, 31, 1
Log 2,>1 page	58617, 6057227, 897, 34, 1e+02

Note the significant reduction in log copy 2's average I/O time, reducing from 1218 to 897 which is much more in-line with the log copy 1 time.

There is also a reduction in the DFWBP counts when compression is enabled as demonstrated in the following extract from the Cache Subsystem RMF report:

SSID	CU-ID	TYPE	CACHE	NVS	I/O	OFF	--CACHE HIT RATE--				-----DASD I/O RATE-----				
							RATE	RATE	READ	DFW	CFW	STAGE	DFWBP	ICL	BYP
2100	7004	2107-961	507G	16G	9754	0.0	5607	4147	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2101	7128	2107-961	507G	16G	6701	0.0	695.4	6006	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2102	7407	2107-961	507G	16G	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

IBM MQ and zEnterprise Data Compression (zEDC) with SMF

IBM MQ allows customers to enable accounting data to be captured and written to the MVS System Management Facility (SMF).

We have found that with short-lived transactions, such as CICS transactions, that the transaction rate can exceed the rate at which IBM MQ can write data to SMF. As a result, some accounting data can be lost – and this loss is reported via the MQ queue manager job log.

In z/OS v1.9, SMF allowed data to be written to log streams rather than data sets and this gave an immediate improvement to the rate at which IBM MQ can write accounting data to SMF.

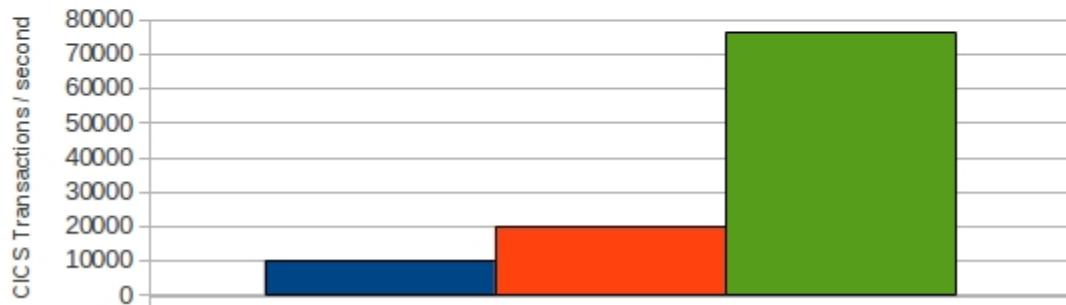
Note: When the transaction rate exceeds the rate at which IBM MQ can write to logstreams, warning messages are only written to the system log.

Using z/OS 2.1 and the zEDC feature, log streams can be compressed using hardware compression which can significantly increase the rate at which MQ can sustain accounting data being written to SMF.

CICS Transaction Rate Achieved

All transactions monitored with MQ Accounting Class(3) enabled

- SMF written to Dataset
- SMF written to LogStream
- SMF written to LogStream with hardware compression



The diagram above shows that moving from SMF data sets to log streams resulted in a doubling of the transaction rate without loss of accounting data.

Using hardware compression on SMF log streams in conjunction with IBM MQ's accounting trace allowed a further 3.8 times higher throughput through a single queue manager to be recorded for accounting purposes.

Chapter 5

How It Works

Tuning buffer pools

This chapter gives an outline of how buffer pools are used and what the statistics mean.

Introduction to the buffer manager and data manager

This describes how buffer pools are used. It will help you determine how to tune your buffer pools.

The data manager is responsible for the layout of messages within one or more 4KB pages, and for managing which pages are used on a page set. A message always starts on a new page and a long message can span many pages. A page can contain persistent messages or non-persistent messages, but not both.

The buffer manager is responsible for reading and writing these pages to the page sets, and for managing copies of these pages in memory. The buffer manager makes no distinction between persistent and non-persistent messages, so both persistent and non persistent messages can be written to the page set.

A buffer pool page is written to a page set at the following times:

- At checkpoint, if it contains any change since it was last written and this is the second checkpoint to have occurred since the first such change.
- Whenever the threshold of less than 15% free buffer pool pages is reached. Pages are then written asynchronously by an internal task. This is referred to as the "15% free threshold".
- When an application has finished with a page and there are less than 5% free pages in the buffer pool.
- At shutdown, if it contains any change since it was last written.
- From V5.3 buffer pool pages which contain non-persistent messages are usually not written to a page set at checkpoint or shutdown.

A page is changed both when a message is put and when it is retrieved, because the MQGET logically deletes the message unless it is a browse.

Pages are usually written by the Deferred Write Process (DWP, although it is sometimes called DWT) asynchronously from user application activity. The DWP writes pages from the buffer pool in least recently used order (that is, from the oldest changed page).

A page is read from a page set data set into the buffer pool at the following times:

- When a message that is not already in the buffer pool is required.
- During read ahead, which is when an internal task reads a few messages into the buffer pool before an application needs them. This happens if the current MQGET does I/O to read a page and was not using MSGID or CORRELID.

Read ahead is most effective when you have a few applications getting short persistent messages with only a few messages per unit of work, because the read ahead is more likely to complete while the application waits for log I/O.

There is no direct user control on read ahead. However, you might be able to improve throughput and response time by using multiple queues on separate page set data sets spread across multiple volumes to reduce I/O contention.

Differences in performance due to the size of a buffer pool depend on the amount of I/O activity between a buffer pool and the associated page set data sets. (Real storage usage, and hence paging, might also be a factor but this is too dependent on individual system size and usage to be usefully discussed here.) The unit of I/O is a page rather than a message.

The effect of message lifespan

This section discusses some message usage scenarios.

- For messages that are used soon after they are created (that is, typically within a minute, but possibly up to 2 checkpoint intervals) and a buffer pool that is large enough to contain the high water mark number of messages, plus 15% free space:
 - Buffer pool pages containing such messages are likely to be re-used many times, meaning that relatively few pages need to be written at checkpoint and almost no pages need to be read.
 - Both CPU cost and elapsed time are minimized.
 - For messages that are stored for later batch processing:
 - All pages containing such messages are likely to be written to the page set data set because they become more than 2 checkpoints old, regardless of buffer pool size. All these pages need to be written again after the messages are used by an MQGET call, for example at the second checkpoint after the MQGET call (because the pages on the page set still contain the messages and must eventually reflect the fact that the messages are now flagged as deleted). However, if pages are reused for new messages before being written to the page set, one write operation will cover the MQGET of the old messages and the MQPUT of the new.
 - MQGET operations can still be satisfied directly from the buffer pool, provided that the pool has not reached the 15% free threshold since the required message was MQPUT.
 - In either case, if the 15% free threshold is crossed, the DWP is started. This uses the least recently used algorithm for buffer pool pages to write the oldest changed buffer pool pages to the page set and make the buffer pool pages available for other messages. This means that any messages written to a page set will have to be read back from the page set if the buffer pool page is reused.
 - This is the least efficient buffer pool usage state. Elapsed time and CPU cost will be increased.
- In many cases (for example, a single queue that is much larger than the buffer pool and is

accessed in first in first out sequence) most messages will have to be read from the page set.

- A busy buffer pool, once in this state, is likely to remain so.

Non-persistent message processing does not require IBM MQ log I/O and thus page set read I/Os might have greater impact on elapsed time.

A buffer pool that is large enough to keep 15% free buffers will avoid any reads from the page set (except after a queue manager restart).

Understanding buffer pool statistics

A page in a buffer pool is in one of five states

Unused

This is the initial state of all pages within the buffer pool.

Changed and in use

The content of the page in the buffer pool is different from the matching page on the page set. Eventually the queue manager will write the pages back to the page set. The page is currently in use by an application, for example a message is being placed within it. When a large message is being put, many pages might be updated, but usually only one page will be in use at a time.

Changed and not in use

The page is the same as "Changed and in use" except that the page is not in use by an application.

Unchanged and in use

The content of the page in the buffer pool is the same as the matching page on the page set. The page is in use, for example, an application is browsing a message on the page.

Unchanged and not in use

The content of the page in the buffer pool is the same as the matching page on the page set, and the page is not in use by an application. If a buffer for a different page is required, the buffer page can be reassigned without its contents being written to disk.

- The term stealable buffers refers to those buffers that are unused or unchanged and not in use. The number of stealable buffers available as a percentage of the total number of buffers affects the behavior of the buffer pool.
- A page can only be written to disk if it is 'changed' and not 'in use'. In some circumstances, pages that are 'changed' and 'in use' are written to disk synchronously after the application has finished with the page - which results in the page becoming 'changed' and not 'in use' only when the I/O completes.
- When a changed page is written to disk (so the version on disk is the same as that in the buffer pool) the page becomes unchanged and not in use.

The data manager issues requests for pages to the buffer manager. If the contents of a page are required, a request to get a page is issued:

- The buffer manager checks to see if the page is already in the bufferpool; if it is, the page status is set to in use and the address of the page is returned.
- If the page is not in the buffer pool, a stealable buffer is located, the page status is set to in use, the page is read in from the page set, and the address of the page is returned.

- If an update is going to be made to the page, the data manager calls the buffer manager with a SET WRITE request. The page is then flagged as changed and in use.
- When an application has finished with the page it releases it and, if no other application is using the page, the status is changed to not in use.

If the contents of the page are not required (for example, the page is about to be overwritten with a new message) a request to get a new page is issued. The processing is the same as above except, if the requested page is not in the buffer pool, a stealable buffer is located but the page is not read in from the page set.

Definition of buffer pool statistics

This section describes the buffer pool statistics. The names given are as described in the assembler macro thlqual.SCSQMACS(CSQDQPST) and is discussed in more detail in the InfoCenter section 'Buffer manager data records'. The names shown in brackets are those used by the program MQ1150 which can print out SMF statistics. (MQ1150 is available as part of performance report "[MP1B](#)").

QPSTNBUF(#buff)	The number of pages allocated to the buffer pool in the CSQINP1 data set at MQSeries startup.
QPSTCBSL(#low)	The lowest number of stealable buffers during the SMF interval.
QPSTCBS(#now)	The number of stealable buffers at the time the SMF record was created.
QPSTGETP(getp)	The number of requests to get a page that were issued.
QPSTGETN(getn)	The number of requests to get a new page that were issued.
QPSTSTW(STW)	The number of SET WRITE requests that were issued.
QPSTRIO(RIO)	The number of pages that were read from the page set.

If the percentage of stealable buffers falls below 15% or the percentage of changed buffers is greater than 85%, the DWP is started. This task takes changed pages and writes them to the page sets, thus making the pages stealable. The task stops when there are at least 25% stealable pages available in the buffer pool.

When the status of a changed page goes from in use to not in use, and the percentage of stealable pages falls below 5% or changed pages is greater than 95%, the page is written to the page set synchronously. It becomes unchanged and not in use, and so the number of stealable buffers is increased.

When a checkpoint occurs, all pages that were first changed at least two checkpoints ago are written to disk, and then flagged as stealable. These pages are written to reduce restart time in the event of the queue manager terminating unexpectedly.

If a changed page was in use during checkpoint processing or when the DWT ran, but should have been written out, the page is written out to disk synchronously when the page changes from in use to not in use.

QPSTDWT(DWT)	The number of times the DWP was started.
QPSTTPW(TPW)	The total number of pages written to page sets.
QPSTWIO(WIO)	The number of write request.
QPSTIMW(IMW)	The number of synchronous write requests. (There is some internal processing that periodically causes a few pages to be written out synchronously.)
QPSTDPMC(DMC)	The number of times pages were written synchronously to disk because the percentage of stealable buffers was less than 5% or changed pages was greater than 95%.

When the data manager requests a page that is not in the buffer pool, a stealable page has to be used.

QPSTSTL(STL)	The number of times a page was not found in the buffer pool and a stealable page was used.
QPSTSOS(SOS)	The number of times that a stealable page was needed and there were no stealable pages available (a short on storage condition).
QPSTSTLA(STLA)	The number of times there was contention when getting a stealable page.

Interpretation of MQ statistics

1. If QPSTSOS, QPSTSTLA, or QPSTDPMC are greater than zero you should increase the size of the buffer pool or reallocate the page sets to different buffer pools.
2. For buffer pool 0 and buffer pools that contain short lived messages:
 - QPSTDWT should be zero and so the percentage QPSTCBL/QPSTNBUF should be greater than 15%.
 - QPSTTPW might be greater than 0 due to checkpointing activity.
 - QPSTRIO should be 0, unless messages are being read from a page set after the queue manager is restarted.
 - A value of QPSTSTL greater than 0 indicates that pages are being used that haven't been used before. This could be caused by an increased message rate, messages not being processed as fast as they were (so there is a build up of messages), or larger messages being used.
 - You should plan to have enough buffers to handle your peak message rate.
3. For buffer pools with long lived messages, where there are more messages than will fit into the buffer pool:
 - (QPSTRIO+QPSTWIO) Statistics interval is the I/O rate to page sets. If this value is high, you should consider using multiple page sets on different volumes to allow I/O to be done in parallel.
 - Over the period of time that the messages are processed (for example, if messages are written to a queue during the day and processed overnight) the number of read I/Os (QPSTRIO) should be approximately the total number of pages written (QPSTTPW). This shows that there is one disk read for every page written.
If the QPSTRIO is much larger than QPSTTPW, this shows that pages are being read in multiple times. This could be caused by application using MQGET by MSGID or CORRELID, or browsing messages on the queue using get next. The following actions might relieve this problem
 - Increase the size of the buffer pool so that there are enough pages to hold the queue, in addition to any changed pages.
 - Move page sets to a different buffer pool to reduce contention between messages from different applications.
 - Use the INDXTYPE queue attribute which allows a queue to be indexed by MSGID or CORRELID and eliminates the need for a sequential scan of the queue.
 - Change the design of the application to eliminate the use of MQGET with MSGID or CORRELID, or the get next with browse option. Applications using long lived messages typically process the first available message and do not use MQGET with MSGID or CORRELID, and they might browse only the first available message.

Example of a badly tuned buffer pool

This example was taken from a production system. Buffer pool 0 contains only page set 0.

The system was being monitored using the ISPF interface on TSO to display information about queues and channels. The initial symptom was that throughput to the distributed MQ systems dropped by a factor of 100.

Table: Buffer pool statistics for intervals		
Field	Previous interval	Problem interval
QPSTNBUF	1050	1050
QPSTCBSL	300	154
QPSTCBS	308	225
QPSTGETP	1800000	23000000
QPSTGETN	16000	13000
QPSTRIO	0	310000
QPSTSTW	508000	432000
QPSTTPW	940	1938
QPSTWIO	59	107
QPSTIMW	29	47
QPSTDWT	0	11
QPSTDMC	0	0
QPSTSTL	84	732000
QPSTSTLA	0	421000
QPSTSOS	0	0

Observations on the problem interval

1. The value for QPSTSTLA (contention when getting a stealable buffer) is 421000. This is extremely high.
2. More than half the request for a stealable buffer had contention
 $(\text{QPSTSTLA}/\text{QPSTSTL}) = 421000/732000$
3. The number of pages read (QPSTRIO) is very high. 310,000 I/O in 30 minutes is approximately 172 I/O per second (about the maximum capacity of the device).
4. QPSTDMC is zero so the buffer pool was not critically short of buffers.
5. QPSTDWT is greater than zero, QPSTCBSL/QPSTNBUF=154/1050 is 14.6%, QPSTTPW=1938, these figures are not unusual.
6. QPSTGETN is lower than the previous interval, but QPSTGETP is significantly higher. Also QPSTSTW is lower, indicating less updates. This implies that there were more requests for MQGET with browse or by MSGID or CORRELID.

What was happening

1. In the mover, information on channels is held in messages on the SYSTEM.CHANNEL.SYNC.QUEUE. At the end of a batch, the messages relating to the channel are retrieved from the queue. The MQGET request uses MSGID which is the index type on the queue in the sample.
2. The SYSTEM.CHANNEL.SYNC.QUEUE was in page set 0 and in buffer pool 0.
3. Normally there were sufficient stealable pages for the whole of the SYSTEM.CHANNEL.SYNC.QUEUE to be kept in the buffer pool.
4. The model queue definitions for command requests and responses pointed to page set 0.
5. For some reason (perhaps the ISPF operator asked for all information about all queues, which produced many response messages) buffer pool 0 filled up.
6. DWT processing moved the older pages out to disk and made the pages stealable.
7. When a channel reached the end of a batch, it had to read pages for the channel from the page set looking for a particular message. Because there were insufficient stealable buffers to hold the whole of the SYSTEM.CHANNEL.SYNC.QUEUE in the buffer pool, stealable pages were reused and so, for example, the buffer that held the first page of the queue was reused and was replaced with the 100th page of the queue.
8. When the next channel reached the end of a batch, it had to read the first page of SYSTEM.CHANNEL.SYNC.QUEUE from disk and re-use a stealable buffer. The stealable buffers were then "thrashing".
9. In time, the problem would gradually have corrected itself as pages on the SYSTEM.CHANNEL.SYNC.QUEUE became changed when messages were put to and retrieved from the queue. However the ISPF panels were used to display information about the system, and pages were being written out to disk again, and the whole cycle repeated itself.

Actions taken to fix the problem

1. The SYSTEM.COMMAND.REPLY.MODEL queue was altered to use a storage class on a different page set, and so in a different buffer pool.
2. The size of buffer pool 0 was doubled. This was not strictly necessary but it allowed room for any unexpected expansion.

Log manager

The log manager is responsible for writing recovery information to the log data sets. This information is used to recover in the event of a failure or a request to roll back recoverable changes. Recoverable resources includes persistent messages and MQ objects. Non-persistent messages are not recoverable and are not handled by the log manager; they are lost at system restart.

This section discusses only recoverable resources.

The log is conceptually a very long buffer. In practice the log is implemented using virtual storage and DASD. The position of information in this buffer is defined by the Relative Byte Address (RBA) from the start of the buffer.

Description of log manager concepts and terms

This section describes the concepts and terms used in this section. They are described more fully in the IBM MQ for z/OS Concepts section of the IBM Knowledge Center.

- Each log buffer is 4096 bytes long and resides in virtual storage.
- The number of log buffers is determined from the OUTBUFF keyword of the CSQ6LOGP macro.
- When the log buffers fill, or an application issues a commit, the buffers are moved from virtual storage to log data sets, called the active log data sets. When the log records have been written, the log buffers can be reused.
- There are at least two active log data sets, which are used cyclically.
- Dual logging describes the situation where the log buffers are written to two log data sets. In the event of the loss of one data set, the other data set can be used. This facility is enabled with the TWOACTV keyword of the CSQ6LOGP macro.
- Single logging is when only one ring of active data sets are used.
- When an active log data set fills up, an archive log data set is allocated and the active log is copied to it. When the copying has completed, the active log data set can then be reused.
- A data set called the bootstrap data set (BSDS) records which RBA range is on which active or archive log. At system restart, the BSDS is used to identify which log data set to use first.
- You can have two copies of the BSDS data set, so in the event of the loss of one BSDS, the other can be used.
- When an active log is archived, the BSDS data sets are also archived.

Other terms used in this description

- The current log buffer is the log buffer that is being filled. When this buffer fills up, the next buffer is used and becomes the current log buffer.
- The logger is a task, running within the queue manager, that handles the I/O to log data sets.
- A log check request occurs while work is being committed. If the data up to the RBA has not been written out to disk, a request is made to the logger passing the RBA value, and the requester is suspended. The logger writes the data up to the RBA out to disk and resumes any tasks waiting for the logger. When the log check request completes, the data has been copied to disk and it can be used in the event of a failure. A log check is issued when:
 - A commit is issued.

- A persistent message is put or got out of syncpoint.
- An MQ object, such as a local queue, is defined, deleted or altered.

Illustration of logging

The following section gives a simplified view of the data that is logged when an application gets a persistent message and issues a commit.

When a message is got, a flag is set to indicate that the message is no longer available. The change to the flag and information to identify the message within the page, along with information to identify the unit of work, are written to the log buffers. During the commit, "end of unit of work" information is written to disk and a log check request is issued with an RBA of the highest value used by the application.

When does a write to the log data set occur?

Log buffers are written to disk at the following times:

- When a log check request is issued. When the application is running under a syncpoint coordinator (for example, CICS Transaction Server) and has issued update requests to multiple resource managers (such as MQ requests) and recoverable CICS resources, the sync level 2 protocol is used at commit time. This causes two MQ log check requests, one for the PREPARE, and the other for the COMMIT verbs.
- If the number of filled log buffers is greater than or equal to the value of WRTHRSH specified in the CSQ6LOGP macro, a request is made to the logger to write out up to the RBA of the previous page.
- When all of the log buffers are in use and there are none free.
- When the system shuts down.

The logger writes up to 128 log buffers at a time to the log data sets, so 129 log buffers require at least two I/O requests, but the buffers might be written out when other applications are issuing log check requests.

How data is written to the active log data sets

The current log buffer is the buffer that is currently being filled with data. When this buffer fills up, the next buffer is used and becomes the current log buffer.

Single logging

If the log check request specifies an RBA that is not in the current buffer, the logger writes up to and including the page containing the specified RBA.

If the log check request specifies an RBA that is in the current buffer, the logger writes any log buffers up to, but not including, the current buffer, and then writes the current buffer up to the requested RBA (a partial page) with another I/O.

Dual logging

If the log check request specifies an RBA that is not in the current log buffer, the I/Os are performed on each log data set in parallel.

If the check request specifies an RBA in the current buffer:

- The logger writes any log buffers up to, but not including, the current buffer. Any I/O to the two data sets is performed in parallel.
- It writes the current log buffer to each log data set. The first time the current buffer is written to the log data sets, the I/O is performed in parallel. Any rewrite of the buffer writes to each log data set in series. This happens when a log check specifies an RBA in the same log buffer, or the log buffer is full and there is a new current log buffer. This is to maintain data integrity in case the update of the current log buffer on disk fails.

Rule of thumb In effect, for a log check request with dual logging, the elapsed time for the write of the current page to the log data sets is the time required for two I/Os in series; all other log writes take the time for one log I/O.

Interpretation of key log manager statistics

Consider an application that gets two messages and issues a commit.

When a message is retrieved, a flag is set to indicate that the message is no longer available. The change to the flag and information to identify the message within the page, along with information to identify the unit of work, are written to the log buffers. The same happens for the second message. During the commit, "end of unit of work" information is written to disk and a log check request is issued with an RBA of the highest value used by the application. data records'. If this is the only work running in the queue manager, the three log requests are likely to fit in one log buffer. The log manager statistics (described in the IBM Knowledge Center section 'Log manager system data records') would show the following:

QJSTWRNW	Number of log writes with no wait	3
QJSTBFFL	Number of log pages used	1
QJSTBFWR	Number of calls to logging task	1
QJSTLOGW	Number of I/O to each log data set	1

In reality, more data than just one flag is logged and there might be more than one I/O involved. This is explained below.

Detailed example of when data is written to log data sets

Consider two applications, each putting a persistent message and issuing a commit. Assume that:

- Each message needs 16 log buffers to hold all of the data
- The WRTHRSH value in CSQ6LOGP is 20
- Dual logging is used

The following figure shows the log buffers used:

Message 1	Message 2	Commit 1	Commit 2
-----------	-----------	----------	----------

B1 B2 ... B15 B16	B17 B18 ... B31 B32	B33	B34
-------------------	---------------------	-----	-----

Where:

- B1...B16 are the 16 log buffers for message 1
- B17...B32 are the 16 log buffers for message 2
- B33 is the log buffer for the commit of the first application
- B34 is the log buffer for the commit of the second application. In reality, each log buffer usually contains information from different applications, so an individual log buffer might contain information from message 1 and message 2.

If the interval between each MQPUT and the commit is relatively long compared to the time taken to do a disk I/O (for example, more than 20 milliseconds), the following happens:

1. The first message is put, buffers B1-B16 are filled.
2. When the second message is being put, and buffer B21 is about to be filled, because the number of full log buffers is greater than the value of WRTHRSH in CSQ6LOGP, this signals the logger to write out pages up to (but not including) the current buffer. This means that buffers B1-B20 are written out, buffers B1-15 in one I/O, and buffers B16-B20 in a second I/O.
3. When buffer B22 is being filled, the number of full log buffers is greater than WRTHRSH so a request is made to the logger, passing the RBA of page B21. Similarly, when writing B23 a request is made to the logger to write out buffer B22.
4. When the I/O to buffers B1-B15 has completed, these buffers are available for reuse, and so the number of full buffers falls below the value in WRTHRSH and no more requests are made to the logger.
5. When buffer B23 is being filled, the number of full log buffers is not greater than WRTHRSH, so a request is not made to the logger.
6. When the logger has finished processing the requests for buffers B1-15 and B16-20, it checks the work on its input queue. It takes the highest RBA found and writes up to that page to the data sets (so it would write out pages B21-B22). In practice, all of the buffers B23-B32 would be filled while the I/O of buffers B1-B15 is happening.
7. When commit 1 is issued, a log check is issued and buffers B23-B32 are written out in one I/O and buffer B33 (the current buffer) written out in a second I/O. The I/O for buffers B21-B32 is performed in parallel, and because this is the first time B33 has been written, the I/O is performed in parallel. The time taken for the commit is at least the time to perform two I/Os.
8. When commit 2 is issued, buffer B33 is rewritten, so the I/O is performed in series. Buffer B34 (the current buffer) is written out and the I/O to the two logs is performed in parallel. This commit request takes at least the time to do three I/O requests. When B34 is rewritten, the I/O is performed in series.

If the interval between the MQPUTs and the commits is very short compared to a disk I/O (for example less than 5 milliseconds), the following happens:

1. As before, when the second message is being put, and buffer B21 is about to be filled, because the number of full log buffers is greater than the value of WRTHRSH in CSQ6LOGP this signals the logger to write out pages up to (but not including) the current buffer. Buffers B1-B20 are written out, buffers B1-15 in one I/O, and buffers B16-B20 in a second I/O. The I/Os to each log data set are done in parallel.

2. If both the commits are issued while the above I/Os are happening, when the I/Os have finished, the logger writes buffers B21-B33 out in one I/O and buffer B34 (the current buffer) in a second I/O. The I/O for buffers B21-B33 is done in parallel, and the I/O for the current log buffer (B34) is also done in parallel to the two log data sets. The next time buffer B34 is rewritten, the I/O is done in series. The following table summarizes which buffers are written in each I/O:

Long interval	Short interval
B1...B15 in parallel	B1...B15 in parallel
B16...B20 in parallel	B16...B20 in parallel
B21...B22 in parallel	B21...B33 in parallel
B23...B30 in parallel	B34 in parallel
B33 in parallel	
B33 in series	
B34 in parallel	
Time taken: 8 I/O.	Time taken: 4 I/O. However, because more data is written in each I/O on average, each I/O takes longer than the long interval case
The next log check request rewrites B34 in series	The next log check request rewrites B34 in series.

The effect of one log I/O containing data from multiple transactions is called coat-tailing. As a general rule, as the amount of data written to the log increases, the response time of requests requiring a log check increases.

In the example above, if the value of OUTBUFF was 80 (giving 20 log buffers) the put of message 2 would be suspended just before the write of buffer 21 because there are no free log buffers because buffers B1-B20 are all in use, with buffers B1-B15 being written to the log data sets. When the I/O completes and buffers B1-B15 are available again, the application can be resumed. The number of times that an application is suspended because no buffers are available is recorded in the log manager statistic QJSTWTB. If you get a nonzero value in this field, you should increase the value of OUTBUFF until the value of QJSTWTB remains at zero.

MQPUT example

Table: Interpretation of log statistics from MQPUT and commit of 100,000-byte messages

QJSTWRNW	Number of log writes with no wait	215
QJSTBFFL	Number of log pages used	2 550
QJSTBFWR	Number of calls to logging task	200

- The information in the table is for 100 messages, so each message used approximately 25 log pages per message. Each log page is 4096 bytes long, so the 25 pages use 102,400 bytes. This includes the information about which pages have been changed, and information about the unit of work.
- For each MQPUT and commit there were two calls to the logging task, one call was made because the number of full log buffers was greater than the value of WRTHRSH (20), the other call was made during the commit.
- To write out 25 pages causes one I/O for 15 pages, another I/O for 9 pages, and an I/O for the current log buffer. The elapsed time taken to log the data is the duration of 4 I/Os, the

parallel I/O for the 15 pages and the 9 pages, and two I/Os in series for the current log buffer.

MQGET example

Table: Interpretation of the log statistics from MQGET and commit of 100 000-byte messages		
QJSTWRNW	Number of log writes with no wait	110
QJSTBFFL	Number of log pages used	29
QJSTBFWR	Number of calls to logging task	102

- The information in the table is for 100 messages so there is approximately one call to the logger per message.
- Only 29 pages were used to hold the log data. This shows that not very much data was logged and the same page used for several requests before the page was full.
- The same page was written out several times, even though it had not been completely filled.
- Because the current log buffer only was written each time, there was one I/O to each log, and because it was for the current buffer, these I/O were done in series.

Interpretation of total time for requests

In some measurements, the time taken to put a 100 000-byte message and a commit was 67 milliseconds on average, and the time to get a 100 000-byte message and a commit was 8 milliseconds on average. In both cases, most of the elapsed time was spent waiting for log I/O.

For the MQGET, the write I/Os to the dual logging devices were done in series. Because little data was written each time the connect time, when data was transmitted to the device, was small and RMF reports showed that the device had a short response time of 3-4 milliseconds. Two I/Os taking 3-4 milliseconds is close to the time of 8 milliseconds.

For the MQPUT, the write of the 15 and the 9 pages were done in parallel, and the write of the current buffer were done in series; in effect the time taken for four I/Os. Because a lot of data was written in a request, this caused a longer connect time, which leads to a longer overall DASD response time. RMF showed a response time of about 16-17 milliseconds for the log DASD. Four I/Os of 16-17 milliseconds is close to the measured time of 67 milliseconds.

What is the maximum message rate for 100 000-byte messages?

If we assume that:

- Put and commit of 100 messages use 2550 buffers (from the figures above)
- Get and commit of one message uses less than 1 buffer
- MQ writes a maximum 128 buffers for every I/O
- The I/O response time when writing 15 buffers per I/O was about 20 milliseconds
- The I/O response time for writing the current log buffer was 4 milliseconds
- There were no delays when writing to DASD (this includes within zOS and within the DASD subsystem)
- Concurrent copies of an application which puts a message, commits, gets the message, and commits again. We can estimate the maximum message rate as follows:
 1. Out of the 2550 log buffers used for MQPUTs, 100 are written as the current log buffer, so 2450 can be written in parallel

2. We can write up to 15 pages per I/O, so 2450 pages need 164 I/Os
3. 164 I/Os, each taking 20 milliseconds gives a total of 3280 milliseconds
4. Each commit writes the current log buffer to each log data set in series. There are 100 commits for puts and 100 commits for gets. For two I/Os in series, each of 4 milliseconds, the total time for writing the current log buffers is $(100 + 100) * 2 * 4$ giving a total of 1600 milliseconds.
5. Total time for the I/O is 3280 + 1600 giving a total of 4880 milliseconds.
6. If it takes 4.88 seconds to process 100 messages, 20.5 messages could be processed in 1 second. This means that the theoretical absolute message rate is 20.5 messages per second.

This is the theoretical maximum with the given assumptions. In practice, the maximum will be different because the assumptions made are not entirely realistic. In a measurement made using a requester/reply application model where a CICS transaction put a 100 000-byte message to a server, and received the same message back, the transaction rate was 10-11 transactions (21 messages) per second.

Chapter 6

Advice

Use of LLA to minimize program load caused throughput effects

IBM MQ sometimes needs to load programs when applications or channels start. If this happens very frequently then the I/O to the relevant program libraries can be a significant bottleneck.

Using the Library Lookaside (LLA) facility of the operating system can result in very significant improvement in throughput where program load I/O is the bottleneck.

The member CSVLLAxx in SYS1.PARMLIB specifies the LLA setup. The inclusion of a library name in the LIBRARIES statement means that a program copy will always be taken from VLF(Virtual Lookaside Facility) and hence will not usually require I/O when heavily used. Inclusion in the FREEZE statement means that there is no I/O to get the relevant DD statement concatenation directories (this can often be more I/O than the program load itself). Use the operating system “[F LLA,REFRESH](#)” command after any changes to any of these libraries.

The following are some specific examples of when programs are loaded:

Frequent use of MQCONN/MQDISC - for example WLM Stored Procedures

Every time an MQCONN is used, an IBM MQ program module has to be loaded. If this is done frequently then there is a very heavy load on the STEPLIB library concatenation. In this case it is appropriate to place the SCSQAUTH library in the CSVLLAxx parmlib member LIBRARIES statement and the entire STEPLIB concatenation in the FREEZE statement.

For example: Ten parallel batch applications running on the same queue manager were used to drive WLM (Work Load Manager) stored procedures, where each application looped 1000 times issuing ‘EXEC SQL CALL Stored_Proc()’. All stored procedures ran in a single WLMSPAS address space. The stored procedures issued MQCONN, MQOPEN, MQPUT (a single 1K nonpersistent message), MQCLOSE, MQDISC, but no DB2 calls were made, and were linked with the MQ/RRS stub CSQBRSTB.

1. We achieved 300 transactions a second with all of the WLMSPAS’s STEPLIB concatenation in LLA (in both the LIBRARIES(..) and FREEZE(..) dataset lists of the parmlib member CSVLLAxx)
2. We achieved 65 transactions a second with just the LIBRARIES(..)
3. We achieved 17 transactions a second without any such tuning

Frequent loading of message conversion tables

Each conversion from one code page to another requires the loading of the relevant code page conversion table. This is done only once per MQCONN, however, if you have many batch programs instances which process only a few messages each then this loading cost and elapsed time can be minimised by including the STEPLIB concatenation in both the LIBRARIES(..) and FREEZE(..) lists.

Frequent loading of exits - for example, channel start or restart after failure

Channels can have a number of separate exits; SCYEXIT MSGEXIT, SENDEXIT and MREXIT for MCA channels, and SCYEXIT, SENDEXIT, RCVEXIT for SVRCONN channels. If a significant number of channels start in a short time then a heavy I/O requirement is generated to the exit libraries.

In this case the CSQXLIB concatenation must be included in the FREEZE(..) dataset lists to gain any benefit as a BLDL is done for every exit for every channel.

Frequent loading of CSQQDEFV

Each time IMS checks to see if it can connect to a particular queue manager, it has to load the CSQQDEFV module. By placing the dataset in both the LIBRARIES(..) and FREEZE(..) lists we saw an improvement in transaction rate of up to 10%.

System resources which can significantly affect IBM MQ performance

Clearly, having more than enough CPU power is desirable in any system.

DASD I/O capability, particularly write response time and data rate through DASD controller NVS can significantly affect the IBM MQ log and hence persistent message throughput. DASD I/O capability, particularly page set reads for MQGET, can affect performance where large amounts of message data require messages to be spilled from buffer pools and later read back from page sets.

For shared queues,

- CF link type can significantly affect performance. ICP links are faster than CBP links which are faster than CFP links.
- Enough CF CPU power must be allowed for, remembering that it is recommended not to exceed 60% busy on a CF.
- CFLEVEL(4) application structures can use DB2 table and log resources for which DASD I/O capability is important for performance.

Large Units of Work

Multiple messages can be processed in a single unit of work, i.e. within the scope of a single commit. Unless changed at your site, the default setting of MAXUMSGS is 10,000 and can be reviewed using the “DISPLAY QMGR MAXUMSGS” command.

Using larger units of work can use additional storage. In the case of messages on private queues, additional storage will be used from the queue managers private storage, whereas shared queue messages will use storage in the CSQ_ADMIN structure.

The MQPUT cost is typically consistent for units of work up to 10,000 messages.

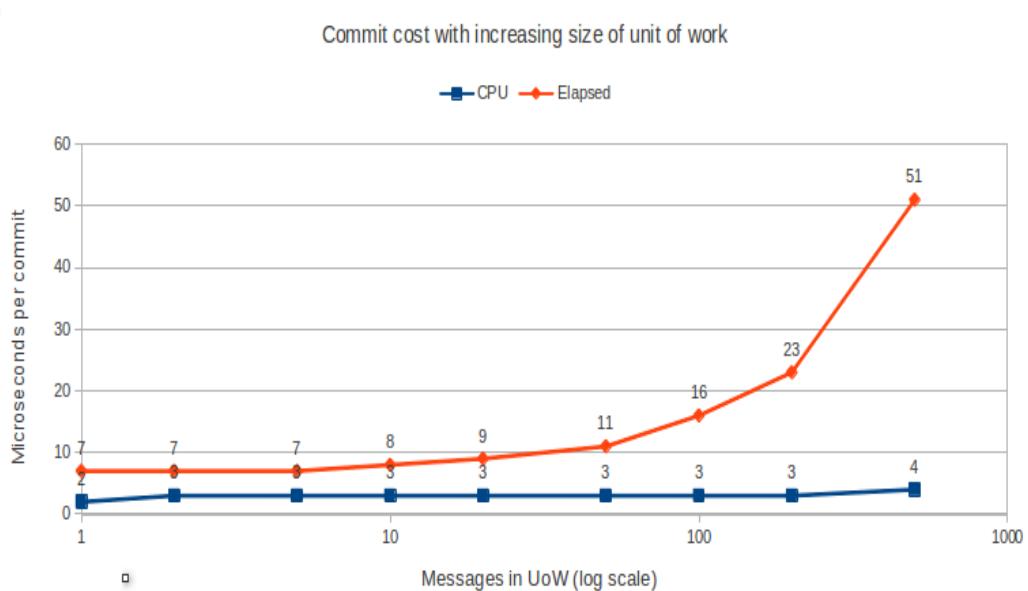
The MQGET cost is typically consistent for units of work up to 10,000 messages except:

- When the queue is indexed and the messages use a common value for the index. In this case, whether using get-next or get-specific there can be additional cost incurred when the unit of work is exceeds 1000 messages.
- If the gets are running at the same time as puts, there will be interaction. For example a task tries to get a message from a queue whilst another task is putting a large number of messages in a unit of work. As the messages being put are in a unit of work, they are not available. This results in the getter task attempting to get each message on the queue. If there are 100,000 messages in the unit of work, the getter task may attempt up to 100,000 gets. If each of these gets takes 1 microsecond, the failed get could cost 100 milliseconds of CPU.

Typically the time of taken to commit will increase as more data needs to be committed. As the number of messages per commit increases, the duration of the commit time is spread across more messages, so the impact is reduced as the number of messages per commit increases.

The following chart shows the CPU and elapsed time per commit as the number of messages in a unit of work increases.

Note: When there is 1 message per commit, for 1000 messages there will be 1000 commits. This means that the commit cost would be 2000 microseconds and the elapsed time would be 7000 microseconds. Contrast this 1000 messages per commit where the commit cost is 4 microseconds and the elapsed time is 51 microseconds.



Application level performance considerations

If and when appropriate consider:

- Is there really a requirement to use persistent messages?
- Processing multiple reasonably small messages in one unit of work (that is, within the scope of one commit)
 - But do not usually exceed 200 messages per unit of work
- Combining many small messages into one larger message, particularly where such messages will need to be transmitted over channels. In this case a message size of 30KB would be sensible.
- The following are particularly important for thin client applications
 - Minimise the number of calls, in particular keep connected, and keep a queue open.
 - Is it necessary to use temporary dynamic queues?
 - Use MQPUT1 rather than MQOPEN, MQPUT, MQCLOSE, unless multiple MQPUTs are going to be issued against the same queue.
- Application requirement for strict message ordering.
- If using IMS message processing regions, preload the IBM MQ modules.

Some applications require messages to be processed in strict order of arrival. This requires that a **single** application instance process a queue of messages. There would be many requester applications but only a single reply application. If this application should fail or slow down due to resource contention, the queue depth could rise dramatically.

Chapter 7

Queue Information

Tuning queues

There are a number of options that can be applied to queues that can reduce cost or help identify problems in the appropriate environment.

Queue option ACCTQ

Specifies whether accounting data collection is to be enabled for this queue. In order for this data to be collected, it is necessary to enable class 3 accounting data. Whilst setting the ACCTQ attribute to a value other than QMGR can allow targeted analysis of costs, there is a risk that when evaluating the data gathered, there will be incomplete data from access to queues where the ACCTQ queue attribute is set to a different value.

Queue option DEFRESP

Specifies the behaviour to be used by applications when the put response type, within the MQPMO options, is set to MQPMO_RESPONSE_AS_Q_DEF.

Using asynchronous puts can improve message put rate and reduce the round-trip time when putting messages using an MQ client application. If your messaging requirements allow it, running with asynchronous puts from a client application can reduce the cost of the put on the z/OS queue managers and channel initiator by between 18% and 55% for messages ranging in sizes 100,000 to 1000 bytes.

Queue option DEFREADA

Specifies the default read ahead for non-persistent messages delivered to the client. Enabling read ahead can improve the performance of client application consuming non-persistent messages. In a queuing model, where the client application is just getting messages from a queue and not putting messages, we have seen the get rate improve 4 times over synchronous gets and costs drop by between 12 and 55%.

High-latency networks, where the time to respond to a request is extended due to a long time in the network can see significant improvements in MQGET – however a request/reply model will not benefit in this way.

Queue option MONQ

Controls the collection of online monitoring data for queues and is supported on local and model queues only. The queue option is used in conjunction with the “RESET QSTATS” command to report the number of messages put and removed from the queue and the peak queue depth since the last reset.

Queue option PROPCtl

This attribute specifies how message properties are handled when the messages are retrieved from the queue. Specifying a value of V6COMPAT can reduce the amount of parsing the queue manager has to complete and can reduce the cost. See the WebSphere MQ for z/OS version 7.0.1 Performance report “[MP1F](#)” for further details.

Maximum throughput using non-persistent messages

What factors affect non persistent throughput

Throughput for non-persistent messages in private queues:

- Is ultimately limited by CPU power assuming messages can be contained within a buffer pool without spilling to DASD page sets.
- Where messages do have to be read from page sets then the I/O rate sustainable to that DASD will be the constraining factor for MQGET.
- In practise, the limiting factor for non-persistent throughput is likely to be in business logic IO rather than anything internal to IBM MQ.

Throughput for non-persistent messages in shared queues depends on:

- For messages up to 63KB (64512 bytes)
 - z/OS heuristics which can change CF calls from synchronous to asynchronous.
 - The type of link(s) between individual z/OS's and the CF(s).
 - This affects the elapsed time to complete CF calls and so influences the heuristics.
 - The CF machine type and CF CPU %BUSY.
- For messages > 63KB
 - As above for up to 63KB messages plus, the throughput performance of the Shared Message Data Set (SMDS) or the DB2 data sharing group tablespace used to store these messages.

Private queue

What is the maximum message rate through a single *private* queue ?

Using a 3 processor MVS image on a 2827-7A1 system running z/OS 2.1 and IBM MQ for z/OS V8.0.0 we could sustain the following non-persistent message rates to a private queue.

V8.0.0 on 2827-7A1	
Message size	Message rate / sec
1,000	79,090
5,000	72,260
10,000	66,820
30,000	52,450
100,000	27,330

Sustained means, in this case, that messages are MQPUT/MQCMIT and MQGET/MQCMIT at about the same rate so that the queue does not get very large.

We run four MQPUT/MQCMIT jobs in parallel with a four MQGET/MQCMIT jobs to obtain these results. Each job has 400,000 iterations.

NOTE: When running in a WLM controlled environment, it is advisable to ensure that the getting application has equal or higher priority than the putting application otherwise there is a risk that the queue depth will increase, resulting in page set I/O as bufferpools fill.

Throughput for request/reply pairs of private queues

The following message rates are for locally driven request/reply scenarios.

Each request/reply scenario uses:

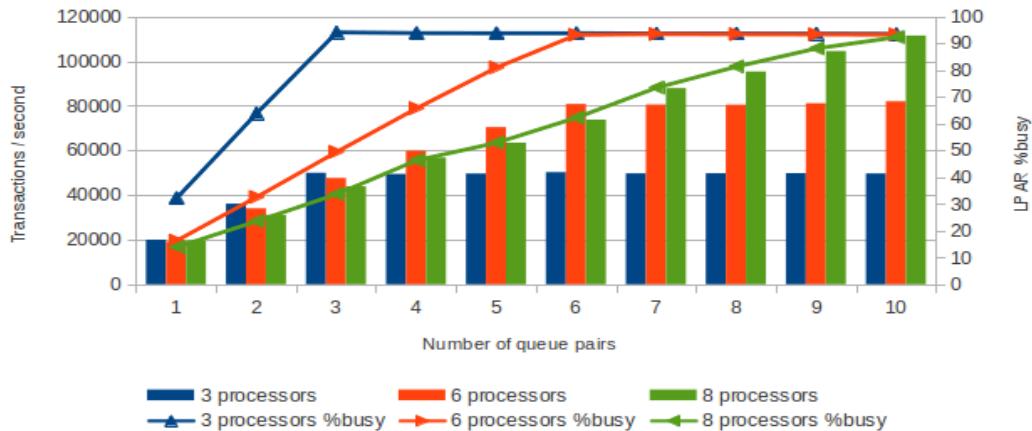
- One or more request/reply applications, each of which uses
 - A pair of queues (a common server queue and a common ‘indexed by MsgId’ reply queue)
 - One or more reply programs using that pair of queues using MQGET, MQPUT, MQCMIT
 - One or more requester programs per reply program using out-of-syncpoint MQPUT and MQGET by MsgId for the reply message specific to that requester.
 - Queue depths were always low, as is usual for request/reply applications. Thus no page set IO is required.

Locally driven Request/Reply on 2827-7A1 using 1000 byte non-persistent messages. Measurements on 8-way LPAR unless otherwise stated.					
Q pairs	Repliers / Q pair	Requesters / Q pair	Msgs/sec	Txns/sec	CPU Microsec / transaction
1	1	1	41375	20687	55
1	4	1	38673	19336	57
1	4	2	58420	29210	67
1	4	3	76052	38026	73
1	4	4	87212	43406	79
1	1	4	60886	30443	57
2	2	4	92587	46293	66
3	3	4	98487	49243	72
4	4	4	90003	45001	76
Following measurements are on 3-way LPAR					
1	1	1	29272	19912	49
2	1	1	52428	36062	53
3	1	1	73601	49953	57
4	1	1	72667	49413	57

The following chart shows how running non-persistent workload with increased numbers of processors can improve the throughput.

Running 1 requester/server pair for each queue pair,
increasing queue pairs

Comparing throughput with varying numbers of processors.
Transactions / second and % busy, using WebSphere MQ v8.0.0

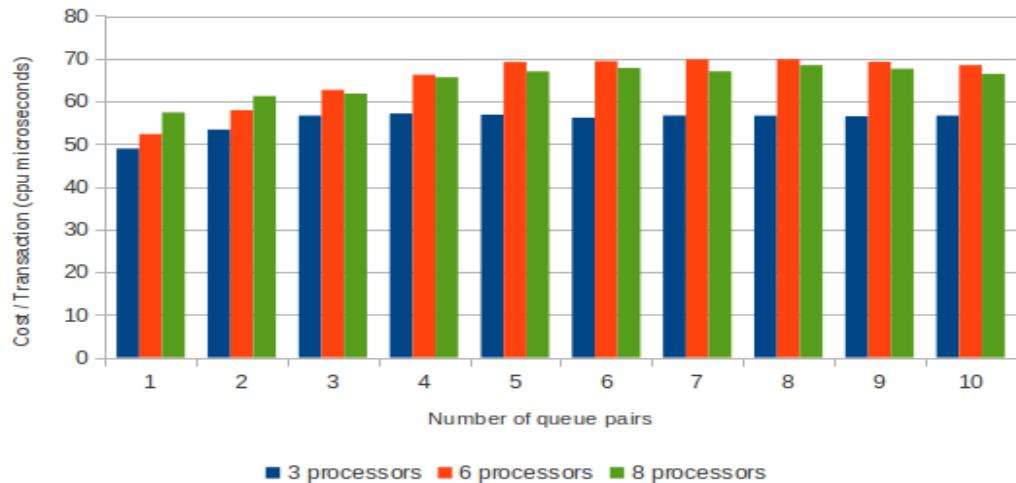


NOTE: When there are 3 processors available, the rate at which the throughput peaks corresponds directly with the number of processors available on the above chart. This pattern is repeated when there are up to 6 processors. As the number of processors exceeds 6, the transaction rates still increase accordingly but the peak rate is less marked.

Transaction cost can be affected by the number of processors available. The following chart compares the transaction costs observed for the previous measurement.

Running 1 requester/server pair for each queue pair, increasing queue pairs

Comparing transaction cost with varying numbers of processors



Shared queue

Throughput for non-persistent messages in shared queues is dependent on

For messages up to 63KB (64512 bytes):

- z/OS heuristics which can change CF calls from synchronous to asynchronous.
- The type of link(s) between individual z/OS's and the CF(s).
 - This affects the elapsed time to complete CF calls and so influences the heuristics.
 - The CF CPU %BUSY

For messages > 63KB that are stored in DB2:

- As above for up to 63KB messages plus the throughput performance of the DB2 data sharing group tablespace used to store these messages.

The performance affect of these factors can vary significantly from one machine range to another.

For messages > 63KB that are stored in shared message data sets (SMDS):

- Refer to “[MP1H: WebSphere MQ for z/OS V7.1.0 Performance Report](#)” for detailed performance of SMDS.

Maximum persistent message throughput - private queue examples

Using a request/reply workload with no business logic where

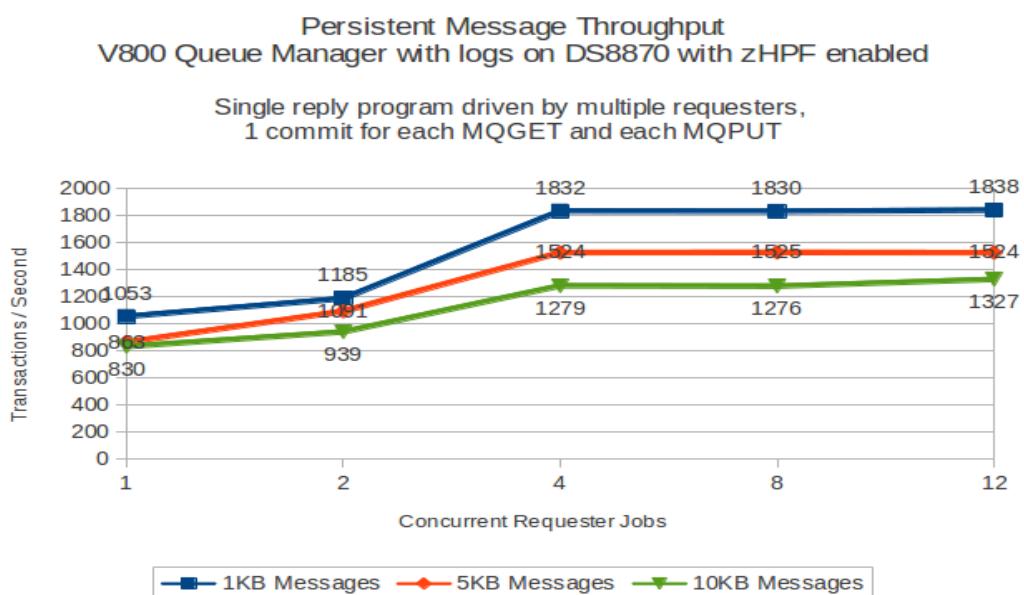
- Requester application(s) use a commit for each MQPUT to a server queue and each MQGET from a reply queue
- Reply application(s) use a commit for each MQGET from the server queue and each MQPUT to the reply queue.
- A request/reply ‘round trip’ uses 2 persistent messages (a request message and a reply message of the same size)
- Thus there is 1 log force for each MQPUT and each MQGET.

We have achieved the following on our 2187-703 z/OS system with DS8870 DASD. On different systems, particularly with different DASD, you may get different results.

As a comparison with older type DASD such as 2105-F20, see “[Maximum Request/Reply throughput \(DS8870\)](#)”.

Strict ordering - single reply application

The following chart shows how many persistent transactions can be processed by a single reply application with an increasing number of requester applications.



By reviewing the class(3) accounting data for the reply application we can see that it is the limiting factor, as can be seen in data taken from the run using 12 requester tasks with 10KB messages e.g.

== Commit : Count	115602,	Avg elapsed	727,	Avg CPU	4
..					
-MQ call-	N	ET	CT	Susp	LOGW
Put : 115603	16	14	1	0	
..					
Get : 115607	14	13	1	0	

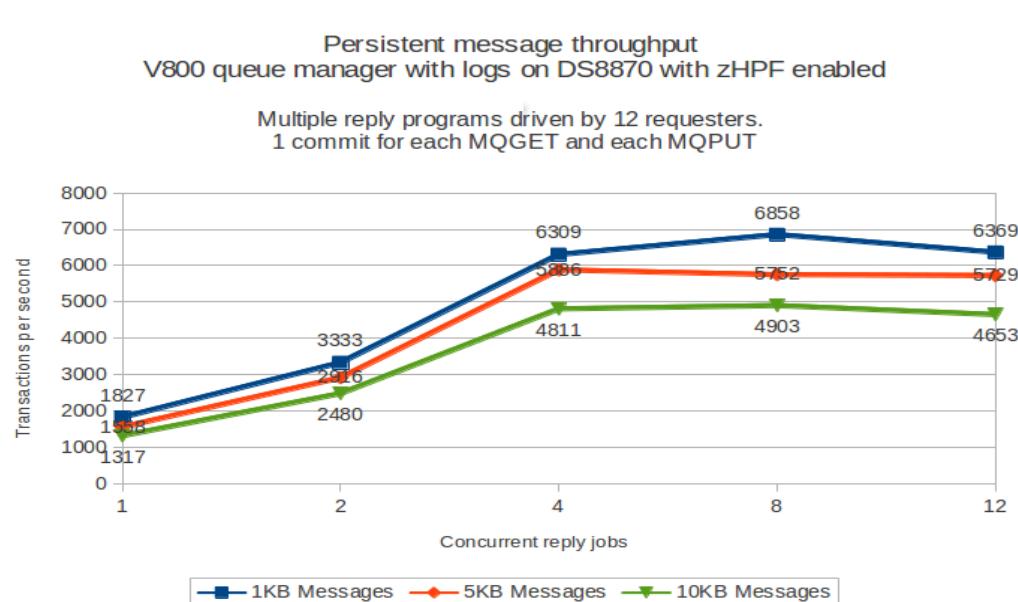
Since the reply transaction is “get, put, commit” we can see that the elapsed time per transaction is: $14 + 16 + 727 = 757$ microseconds.

As the reply application is single threaded, it can process a maximum of 1321 transactions per second (1,000,000 CPU microseconds per second divided by elapsed time of a transaction).

The chart shows 2653 messages of 10KB were processed with 12 requester tasks running – which is the same as 1327 transactions per second, which is approximately 100% of the maximum possible transactions processed.

Increasing number of reply applications

The following chart shows persistent message throughput with an increasing number of reply applications and many (12) requester applications.

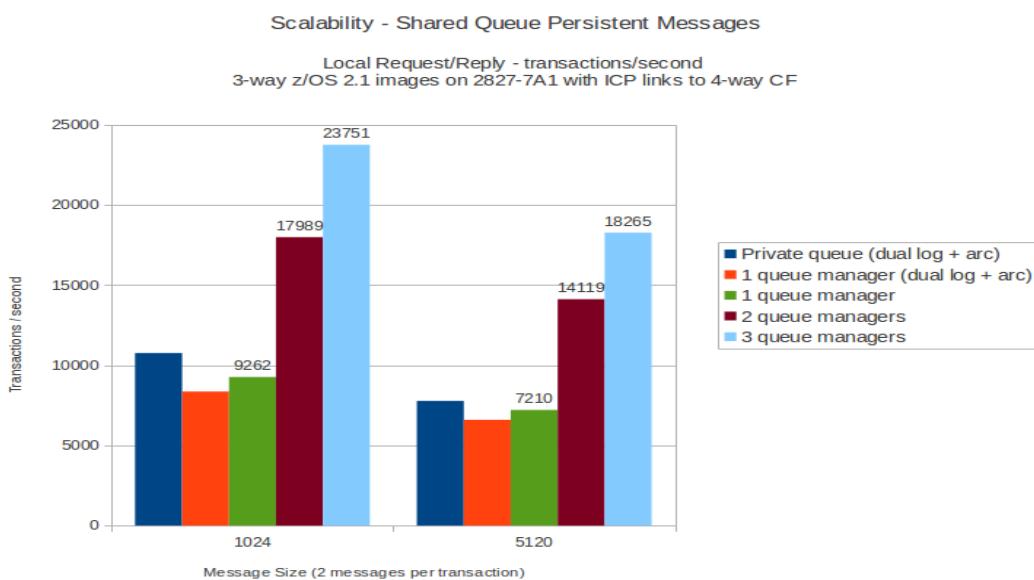


Maximum persistent message throughput - shared queue examples

We have processed more than 59000 1KB persistent messages per second with three queue managers, each on a separate z/OS, using a pair of shared queues when zHPF is enabled.

Persistent message throughput is limited by the rate at which data can be written to the log. Having multiple queue managers each with its own log allows a many times increase in the throughput. Using shared queues means that this many times increase is available through a single queue or set of queues.

The subsequent measurements were run using queue managers running CFLEVEL(5), using default offload thresholds. Due to the size of the messages and the depths of the queues, no offload capacity was required, so the offload medium is irrelevant in these measurements. In all following configurations, zHPF is not enabled.



NOTE: Dual logging and no archiving used unless otherwise stated.

These results were obtained on a parallel sysplex LPARed out of one 2827-7A1 box with a connected DS8870 DASD subsystem. Real production parallel sysplexes would need, and might reasonably be expected to have, sufficient log DASD I/O rate capacity for the required number of logs and archives.

Results on 2827-7A1 systems were obtained using IBM MQ V8.0.0.

“Local Request/Reply” is a set of identical request applications and a set of identical reply applications running on each queue manager such that requesters MQPUT a message to a common server shared queue and MQGET their specific reply message from a common reply shared queue that is indexed by MSGID. The reply applications MQGET the next request message from the common queue, MQPUT the specific reply message to the indexed shared queue and MQCQUIT. Thus there are two messages completely processed (that is created with MQPUT and consumed with MQGET) for each request/reply transaction.

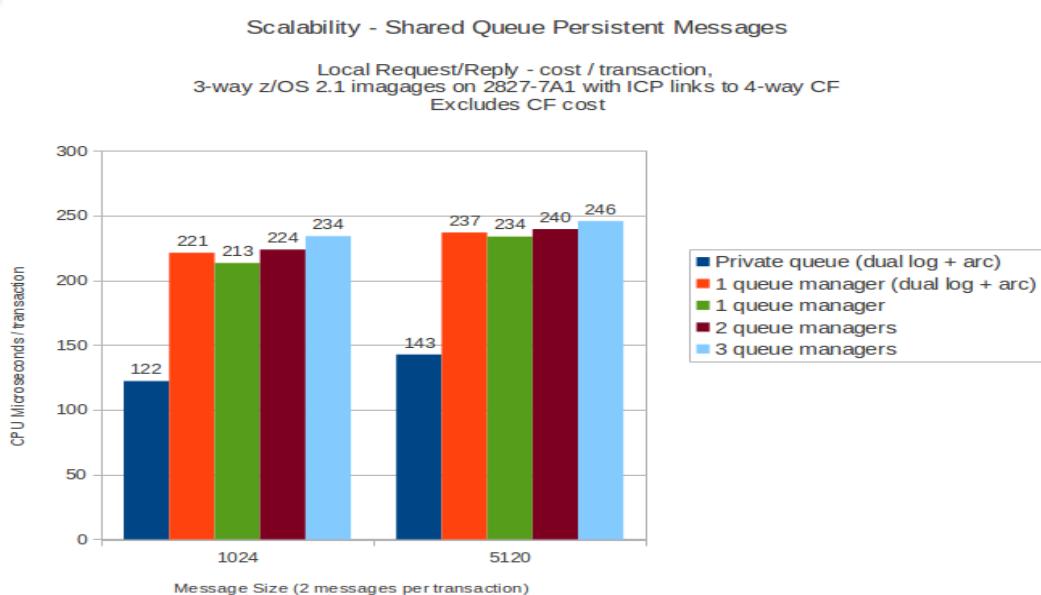
The preceding chart demonstrates the following.

- More than 45000 messages per second (two messages per transaction) with 1KB messages.
- More than 36000 messages per second with 5KB messages.

- Single queue manager workload for shared queue saw the machine running at 62% of capacity compared to 43% of capacity for private queues.
- Archiving versus no archiving can have an effect on throughput of up to 10% for 1 queue manager (dual logging and archiving) versus 1 queue manager.
- Scalability for 1 to 3 queue managers, where there is sufficient:
 - log DASD capacity
 - CF link connectivity
 - CF processing power.

Shared queue persistent message - CPU costs

CPU costs for shared queue are more than usually difficult to estimate from measurements of individual IBM MQ operations. These measurements are the most representative of likely costs for real workloads. This is because they include the interactions between the CF and the queue managers in real life queue sharing under load including waiting MQGET situations. These CPU milliseconds are derived from RMF reported ‘MVS BUSY TIME PERC’ for each **total system**. Thus they include all system overheads and are larger than would be found from adding ‘WORKLOAD ACTIVITY’ reported CPU usage by address space.



NOTE: Unless otherwise specified, dual logging and no archiving are used.

Based on the preceding chart, a rule of thumb may be derived that shared queue persistent CPU costs compared to ‘best case’ private local queue:

- Of the order 170% more than for 1000 byte persistent messages. Each extra queue manager adds 5% to the CPU cost.
- Of the order 160% for 5000 byte persistent messages. Each extra queue manager adds 2% to the CPU cost.

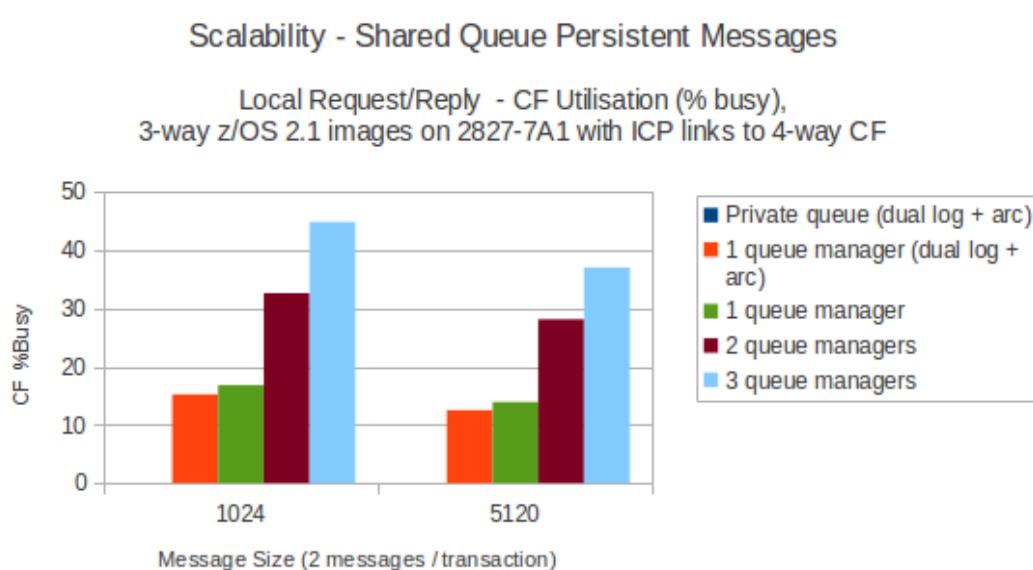
‘Best case’ means all messages remain within the buffer pool. One of the advantages of shared queue is that there can be enough capacity to keep going even when there is an application instance outage.

With private local queues any such outage could severely restrict throughput and/or cause buffer pools to fill with consequently more expensive performance until any backlog is cleared.

Shared queue persistent message - CF usage

MQ calls to the CF are mainly to the application structures. There is no difference in the number and type of calls between persistent and non-persistent messages. There are more calls to the CSQ_ADMIN structure for persistent messages.

The following chart shows the RMF reported ‘CF UTILIZATION (% BUSY)’ matching the persistent message local request/reply charts above.



As discussed in “[When do I need to add more engines to my CF?](#)”, the CPU “% Busy” figure of the CF remains below 50%, therefore we would surmise that there is sufficient CF capacity for this workload. Were more queue managers to be added driving the workload above 50% we would advise activating an additional engine to the CF. The number of asynchronous calls increases as the CPU usage increases, causing a slower response from the CF.

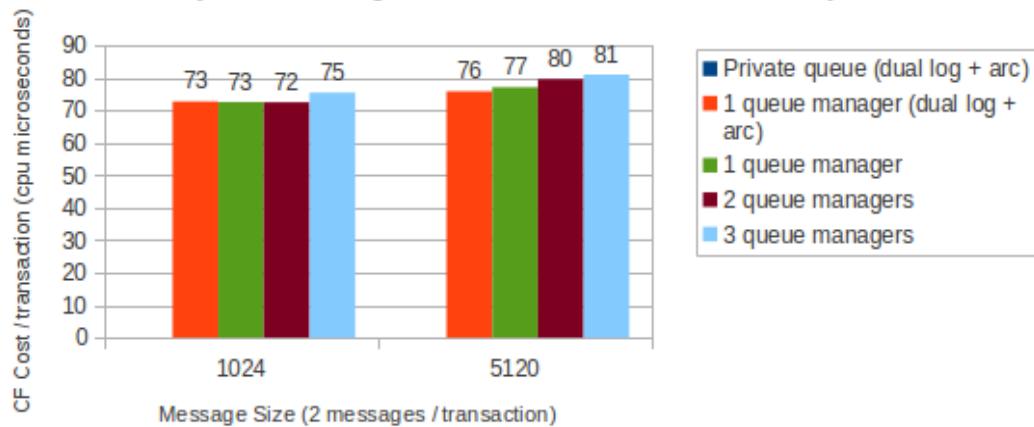
A rule of thumb for CF cost is about 36 CF microseconds per message (72 CF microseconds per transaction) for 1000 byte messages when using ICP links.

For 5000 byte messages the CF cost is 77 CF microseconds per message when using ICP links. CF costs per message do not change significantly with increasing number of queue managers unless the proportion of asynchronous requests increases as a result of adding additional queue managers.

The following chart shows the cost in the CF per transaction.

Scalability - Shared Queue Persistent Messages

Local Request/Reply - Coupling Facility cost/transaction,
3-way z/OS 2.1 images on 2827-7A1 with ICP links to 4-way CF



Note: Were there insufficient CPU capacity in the CF, the number of asynchronous requests would have increased which would also result in an increase to the CF cost per transaction.

Message ordering - logical groups

Messages on queues can occur, within each priority order, in physical or logical order.

- **Physical order** is the order that in which the messages arrive on a queue.
- **Logical order** is when all of the messages and segments within a group are in their logical sequence, adjacent to each other, in the position determined by the physical position of the first item belonging to the group.

These physical and logical orders can differ because:

- Groups can arrive at a destination at similar times from different applications, therefore losing any distinct physical order
- Even with a single group, messages can get arrive out of order because of re-routing or delay of some of the messages in the group.

There are 2 main reasons for using logical messages in a group:

- You might need to process the messages in a particular order
- You might need to process each message in the group in a related way

Does size of group matter?

When a message group consists of large numbers of messages, there is the potential for deep queues, with many uncommitted messages.

Should the transaction fail, there is the potential for a longer back-out time.

We found that there was no significant overhead associated with putting messages in logical groups.

Large groups of small messages OR small groups of large messages?

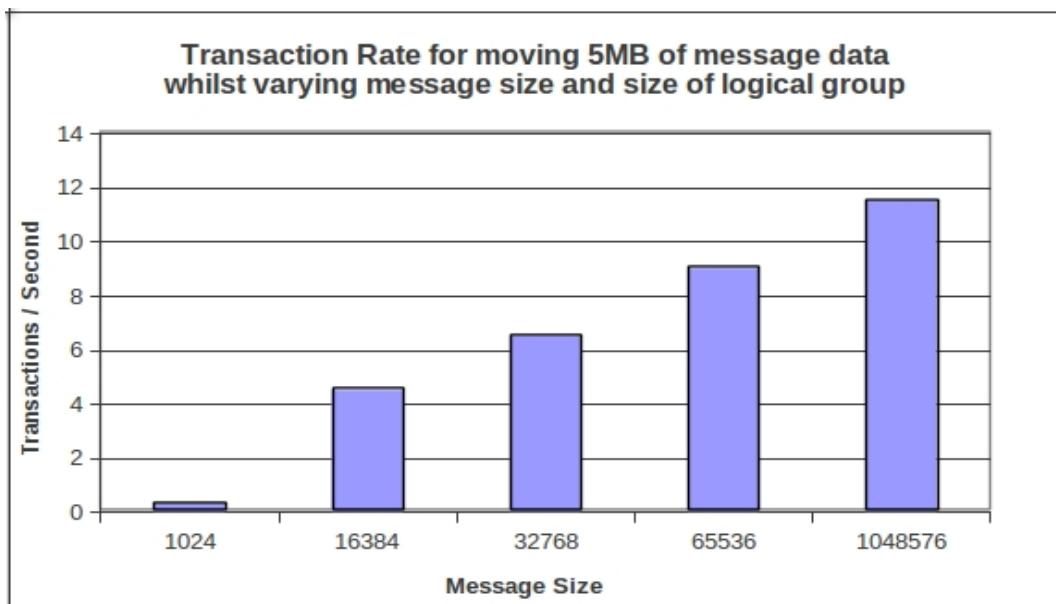
Purely from an MQ perspective it is more cost-efficient and faster to transport small logical groups containing large messages than it is to transport large groups with small messages.

To show a comparison, the following example demonstrates a transaction that moves 5MB of data.

In this example, a transaction is:

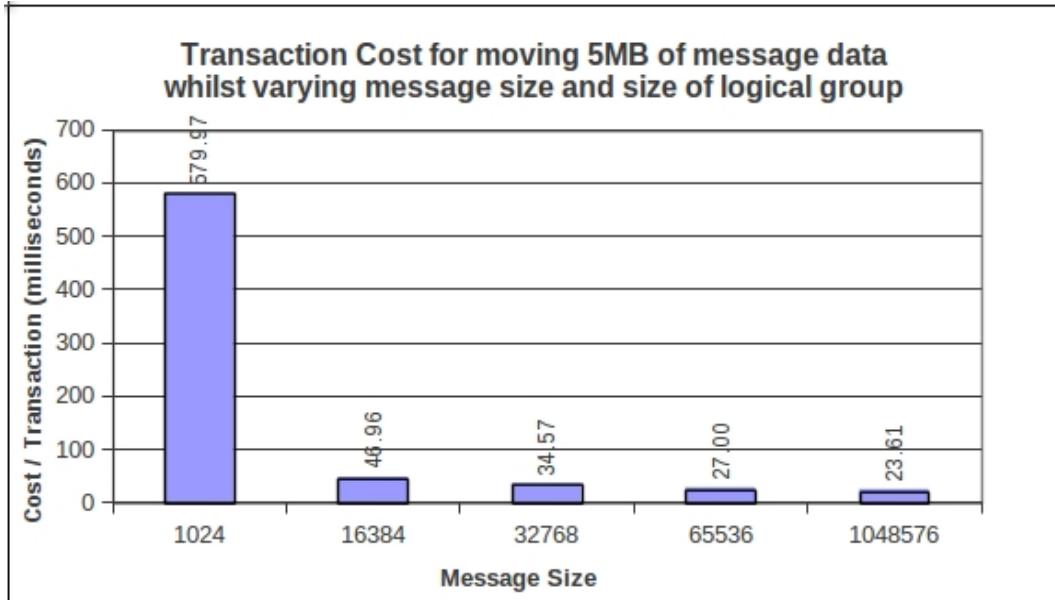
- An application that puts the specified number of persistent messages in a logical group, commits the group and then waits for a single reply message.
- The costs include the application that puts the messages in a logical group and the application that processes the logical group and sends a reply message.
- All measurements were performed on a queue manager using WebSphere MQ v7.0.0 on a single z/OS 1.9 LPAR with 3 dedicated processors from a z10 EC64.

Message Size	Group Size	Message volume transported (message size * group size)
1KB	5000	4.88MB
16KB	320	5MB
32KB	160	5MB
64KB	80	5MB
1MB	5	5MB



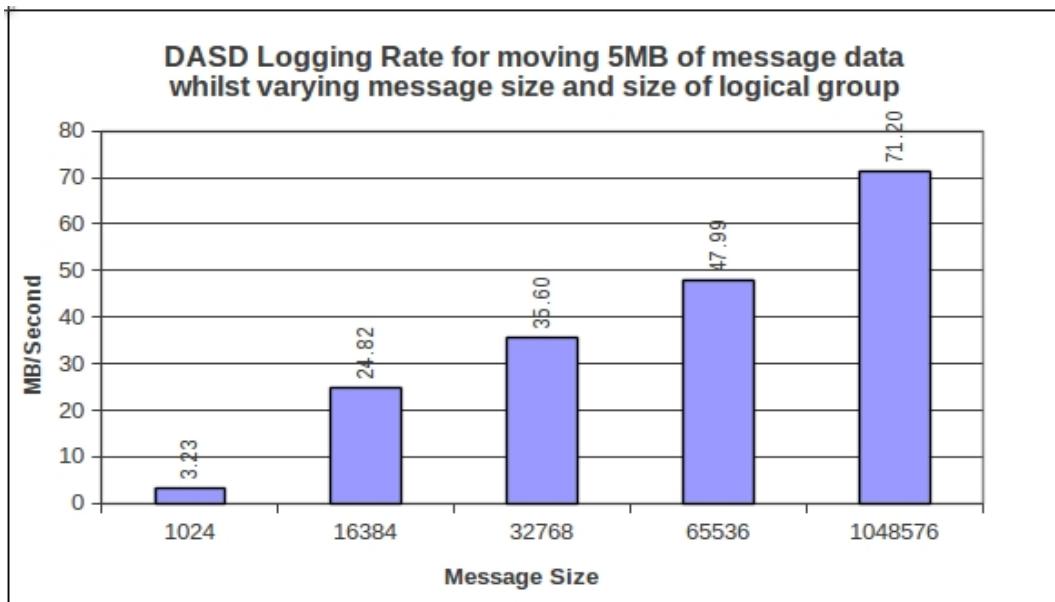
Notes on preceding chart:

- Using a logical group of 5000 with 1KB persistent messages, the achieved transaction rate was 0.3 transactions per second.
- Using 16KB persistent messages with a logical group of 320, the transaction rate increased to 4.5 per second, an increase of 15 times.
- Using 1MB messages with logical groups of 5 messages, the transaction rate increasesd to 11.5 per second, an increase of 38 times.



Notes on preceding chart:

- From an MQ perspective, it is clearly less expensive to process fewer large messages in a logical group than many smaller messages.



Notes on preceding chart:

- When using small (1KB) messages, the rate at which the queue manager can write the logs is much lower (around 16MB/second).
- By contrast, when using large messages, the queue manager can log much faster (70+ MB/second for 1MB messages) and in the above measurements that limit is being reached.
- When batching the application messages into fewer MQ messages, there are less MQ overheads – for example there are only 5 MQMDs logged rather than 5000 MQMDs for a group containing 1KB messages.

Application tuning

How much extra does each *waiting* MQGET cost?

The cost of an MQGET with wait is insignificant - approximately 1 microsecond on a 2817-703. This cost is not dependent on message length, persistence, or whether in or out of syncpoint.

If you have more than one application waiting for a message on a particular queue then every such application will race for any newly arriving message. Only one application will win this race, the other applications will have to wait again. So if you have, for example, five applications all waiting for a message on a particular queue the total cost to get the message is the cost of a successful MQGET, (which does depend on message length, persistence, and whether in or out of syncpoint), plus 5 times 1 CPU microsecond (2817-703).

NOTE: Multiple applications in a get-with-wait can ensure processing throughput even if the cost is slightly higher at low-volume periods.

How much extra does code page conversion cost on an MQGET?

Code page conversion from one single byte character set to another using MQFMT_STRING costs about the same as a basic MQGET out of syncpoint for the same non persistent message size.

DBCS to DBCS conversion costs are of order 4 times a basic MQGET out of syncpoint for the same non-persistent message size.

Event messages

The cost of creating each event message is approximately the same as MQPUT of a small persistent message.

Triggering

For shared queue, there can be a trigger message generated on all queue managers in the QSG. If there are many trigger monitors, only one will get the message, so there may be multiple unsuccessful gets.

Trigger EVERY is suitable when there are low message rates. You should consider having long running transactions to drain the queue or refer to "[A pattern for implementing WebSphere MQ CICS Adapter](#)".

If trigger every is used with a high message rate, this can add significantly to the CPU cost due to all of the trigger messages generated and any additional processing, for example starting CICS transactions.

What is the cost of creating a trigger or event message?

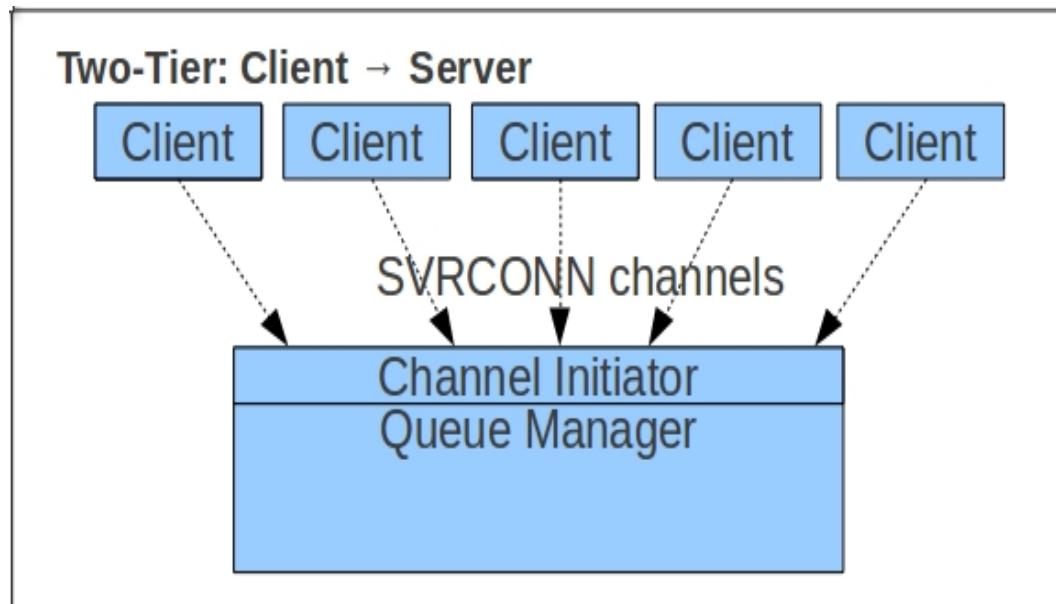
The cost of creating one trigger message is approximately the same as an MQPUT of a small non-persistent message (less than 100 bytes).

When evaluating the cost of triggering, remember to include the cost of the process initiation.

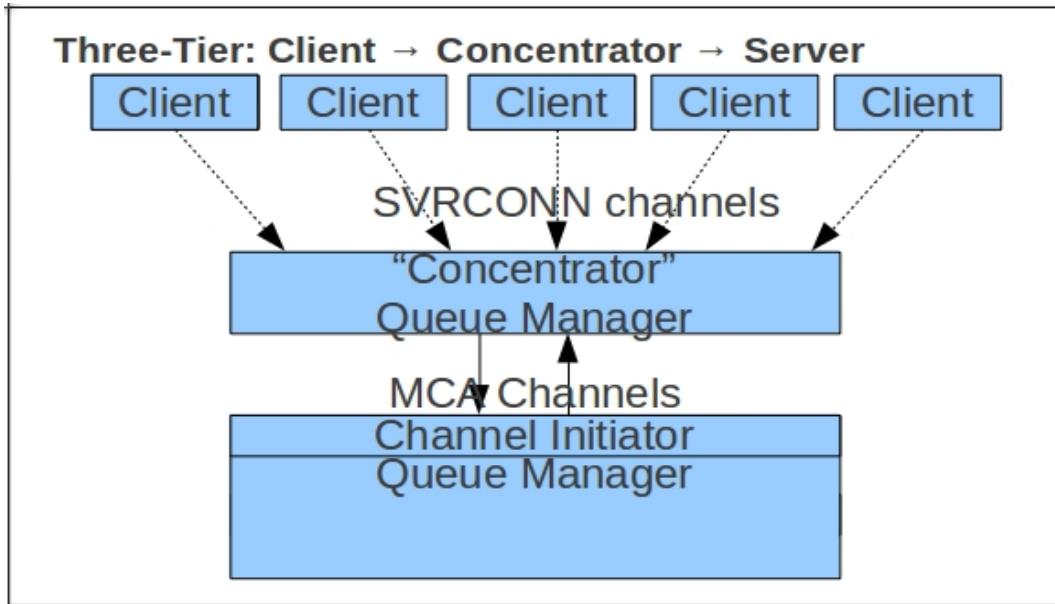
Chapter 8

Two / Three Tier configurations

A typical two-tier configuration is shown in the following diagram. It shows a number of IBM MQ clients connecting using SVRCONN channels directly into the queue manager's channel initiator address space.



A typical three-tier configuration is shown in the following diagram, which uses a concentrator queue manager to accept the SVRCONN connections from the clients and use a single pair of MCA channels to send the messages onto the target queue manager.



Why choose one configuration over the other?

There are several performance factors that should be considered when deciding whether to use a 2 or 3 tier configuration.

- Cost on the z/OS platform
- Achievable rate (latency / persistence / maximum throughput for a channel)
- Number of connecting tasks (footprint)

It should be noted that performance is not the only reason to choose between a 2 or 3 tier configuration. For example if high availability (HA) is a key concern, using a 3 tier model may make the configuration more complex.

Cost on the z/OS platform

The cost of transporting data onto the z/OS platform is often a key criteria when deciding whether to use a two or three tier model.

The cost of connecting directly into a z/OS queue manager via SVRCONN channels can be higher than accessing the z/OS queue manager via MCA channels, from a distributed queue manager, particularly with short-lived connections, where the high connect cost forms a larger proportion of the total cost.

As the number of messages processed during a connection increases, the relative cost of the MQ connect decreases in relation to the total workload. For example:

- If the client connects, puts a 2KB message and then disconnects, the relative cost of the connect is high.
- If the client application were to follow this connect-put-disconnect model but the message is much larger, e.g. a 1MB message, the relative cost of the connect would be much lower.
- Similarly if the client application were to connect, perform many puts and gets, then disconnect, the relative cost of the connect is low.

The key factors relating to cost would be:

- How much work is processed under a single connection, i.e. are the clients long-lived or short-lived?
- The size of the messages.

With very long running transactions or where connection pooling is used resulting in long SVRCONN instances, the costs on z/OS of servicing a SVRCONN connection may be similar to a pair of SDR-RCVR channels.

With regards to MCA channels, as can be seen in the section “[Costs of moving messages to and from MVS images](#)”, achieving larger batch sizes can reduce transaction cost. This means that more efficient batch sizes can be achieved when multiple clients are putting messages to the distributed queue manager.

Achievable Rate

Volume of data – at channel capacity

The volume of data that each client is likely to send/receive may influence any decision on two or three tier configurations.

A channel, whether a SVRCONN or an MCA channel will have a maximum capacity on any particular network and this will depend on a number of factors including network capacity and latency.

If the combined messaging rate of the clients exceeds the maximum capacity of a single channel, using a 3-tier model may result in reduced throughput, however this can be alleviated by using multiple MCA channels between the distributed and z/OS queue managers.

Latency

Adding the third tier in the form of a distributed queue manager may add latency to the time to transport data from client to z/OS or vice versa. In a low latency network or one with short distance between distributed queue manager and z/OS queue manager this may not be a significant amount.

The transport time between distributed and z/OS queue managers may be further reduced if the distributed queue manager is in a zLinux LPAR and the connection is configured to use HiperSockets.

Persistent Messaging

In the case of persistent messages, adding in a second queue manager will mean that the messages are logged twice, once on the intermediate queue manager and again on the z/OS queue manager, which will add latency to the message flow.

In addition with persistent messages that flow over an MCA channel, each one will be processed serially by the channel initiator adaptor tasks, whereas multiple SVRCONN channels could exploit separate adaptor tasks which in turn can drive the queue managers logger task more efficiently.

Number of connecting tasks

The channel initiator on z/OS has a limit of 9,999 channels, as defined by the MAXCHL attribute, however the number of channels that can be run will depend partially on the size of the messages being used. For further information, please refer to the section “[What is the capacity of my channel initiator task?](#)”

A distributed queue manager is not subject to the same 2GB storage limit as a z/OS channel initiator and as such can be configured to support many times the number of client connections that a z/OS channel initiator can support.

As has been documented in the performance report [MP1J](#), the footprint of a SVRCONN channel is 177KB when a 1KB message is being sent and received over a channel configured with SHARECNV(0).

By contrast an MCA channel that sends or receives a 1KB message uses 107KB – however if the connecting task requires a message to be sent and received, it will require 2 channels, with a combined footprint of 214KB.

This suggests that the SVRCONN has a lower footprint, however when multiple clients need to attach, it can be more efficient from a storage usage perspective to use an intermediate queue manager as a “concentrator”, allowing the MCA channels to support multiple clients concurrently.

Measurements

The following configurations were measured:

- Local bindings – requesting application running on z/OS.
- Requesting application uses bindings connection to distributed QM and then use SDR-RCVR channels to interact with z/OS QM.
- Client connection directly to z/OS QM, using SHARECNV(0) and SHARECNV(non-0)
- Client connection to local distributed QM and then use SDR-RCVR channels to interact with z/OS QM.
- Client connection to remote distributed QM and then use SDR-RCVR channels to interact with z/OS QM.

For each of these configurations, two models of requesting application were used:

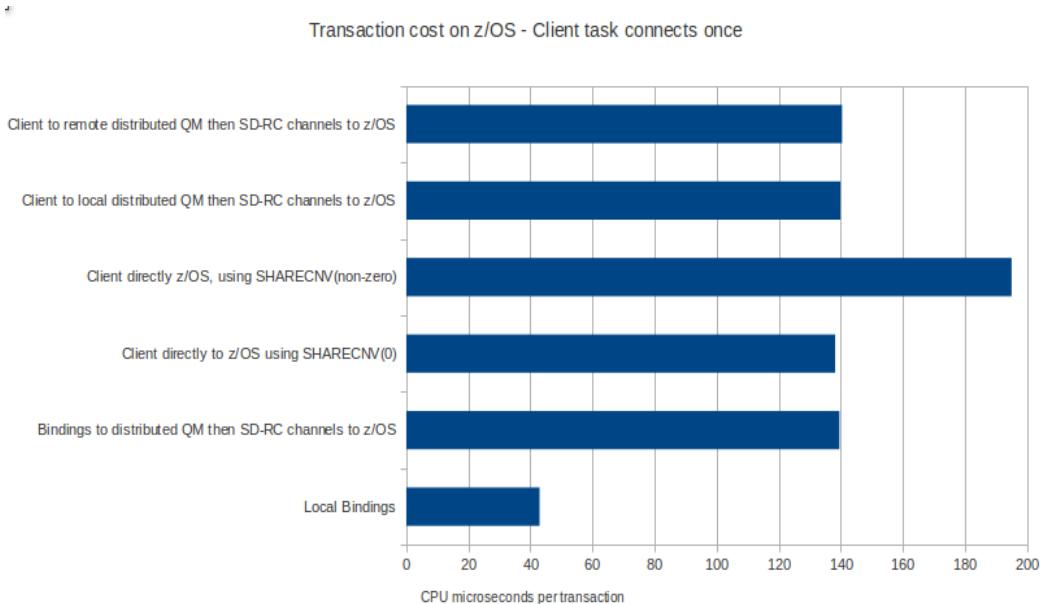
1. Requesting applications use model of: connect, [put, get]*100,000, disconnect.
2. Requesting application use model of: [connect, put, get, disconnect]*100,000.

In each case:

- Messages used were 2KB non-persistent.
- There was a set of long-running batch tasks on z/OS that got the input messages and generated a reply message.

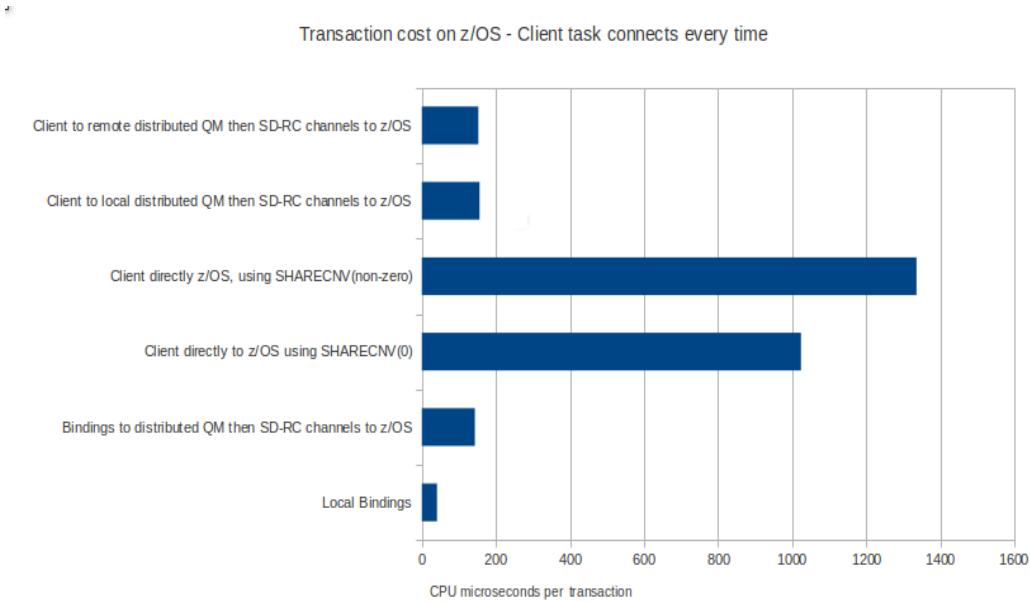
The following 2 charts show the costs of these configurations and include the queue manager, channel initiator, TCPIP and server application costs per message put and got.

CHART: Transaction cost with model: connect, [put, get]*100,000, disconnect



In the preceding chart, the cost of using the SVRCONN channel with SHARECNV(0) in a 2-tier model is similar to that of an application connecting either using bindings or client to a distributed queue manager and that queue manager then using MCA channels into the z/OS queue manager.

CHART: Transaction cost with model: [connect, put, get, disconnect]*100,000



The preceding chart shows that when a client is connecting to the z/OS queue manager for a short period of time, the costs increase significantly.

In each case, connecting a SVRCONN channel with SHARECNV greater than 0 results in additional CPU cost, however this configuration does offer other benefits including asynchronous gets.

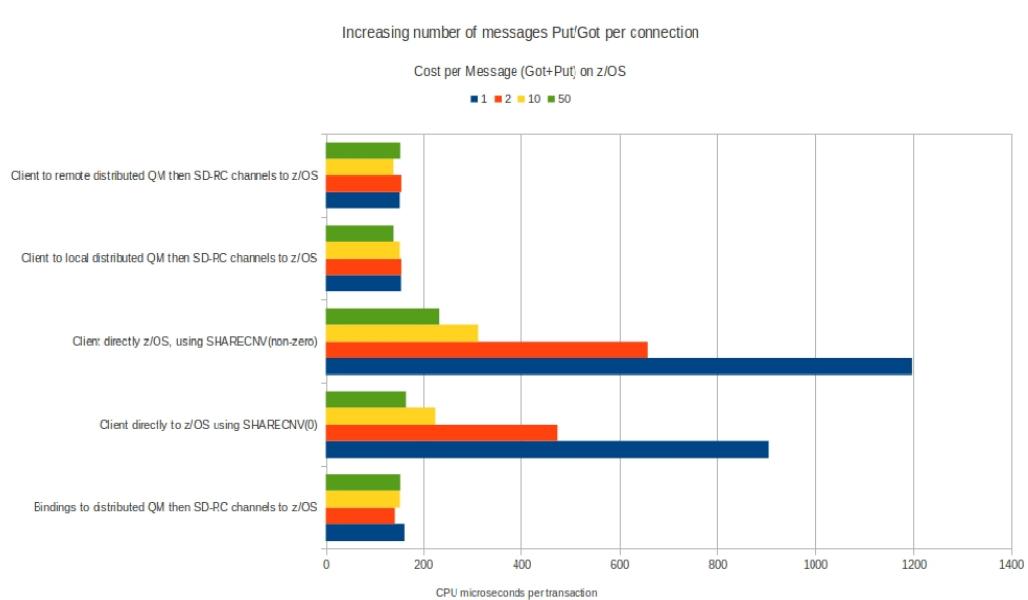
Regarding round-trip times (latency of the workload), the configurations achieved the shortest round-trip time were as per the order they were described earlier i.e. local bindings had shortest round-trip

time and “client to remote distributed queue manager and then use SDR-RCVR channels to z/OS” had the highest round-trip times.

When using shared conversations (SHARECNV larger than 1), the cost of frequently connecting applications can be reduced when there is already 1 or more active conversations when the new connection is requested and there is capacity available (a difference between SHARECNV and the value of CURSHCNV - from a “DISPLAY CHSTATUS” command).

The number of messages processed during the life-span of a channel can affect the cost of a transaction. The following chart provides an example when the number of messages is increased from 1 to 50 messages between connect and disconnect:

CHART: Varying the number of messages processed within connect to disconnect



The preceding chart shows that for a SHARECNV(0) channel, as the number of messages processed between the connect and disconnect increases, the cost per message got and put on z/OS drops significantly, from 905 microseconds when only 1 message is got and put, to 165 microseconds when 50 messages are got and put.

Chapter 9

IMS Bridge: Achieving best throughput

The IBM MQ IMS bridge, known as the IMS Bridge, provides the capability to schedule IMS transactions directly on IMS from an IBM MQ message without the need to use an IMS trigger monitor. The IMS Bridge, which is a component of the IBM MQ for z/OS queue manager, communicates with IMS using the IMS Open Transaction Manager Access (OTMA) service: The IMS bridge is an OTMA client.

When an IMS transaction is driven from a 3270-type screen, any data entered on the screen is made available to the transaction by the IMS GU call. The transaction sends its response back to the terminal using the IMS ISRT call.

An IBM MQ application can cause the same transaction to be scheduled by using the IMS Bridge. An IBM MQ 'request' message destined for IMS, typically with an MQIIH header, is put to an IMS bridge queue. The message is retrieved from the IMS bridge queue by the queue manager and sent to IMS over OTMA logical connections called transaction pipes or tpipes, where the IBM MQ message data becomes input to the IMS GU call. The data returned by the ISRT call will be put into the reply-to queue, where the IBM MQ application can retrieve it using a standard MQGET call. This sequence of events is a typical use of the IMS Bridge and forms the basis of the measurements presented in this section. The IBM MQ request message and its associated reply are referred to as a message-pair or transaction in the rest of this chapter.

This chapter will also provide:

1. Further information on how the IMS Bridge works
2. Suggestions on tuning the IMS subsystem for use with IBM MQ
3. Impact of using Commit Mode 0 or 1
4. How to identify when additional resources are required
5. Throughput achieved on our machines using a standard configuration as detailed in the "Initial Configuration" section below.

Initial configuration

The measurements have been performed using:

- An IMS subsystem
- 3 queue managers in queue sharing group.
- 3 z/OS LPARs running on a 2084-332. Measurements were run on LPAR 1 unless otherwise stated.
 - *LPAR 1 and LPAR 2 are configured with 3 dedicated processors (each LPAR rated as approximately 2084-303)*
 - *LPAR 3 configured with 5 dedicated processors, rated as 2084-305.*
 - *An internal CF with 3 processors.*
- All jobs run were managed using WLM service classes such that the execution velocity is 50% or higher.
- Batch applications were run to drive the workload. Unless otherwise stated, 1KB non-persistent messages were used.
- Unless otherwise stated, the IMS was on the same image as the queue manager and has a varying number of MPRs to process the workload.
- The IMS transaction run issues a “GU” to get the message, then sends the reply using “ISRT” and then if there is another message will issue the “GU” and repeat, otherwise the transaction will end.
- Since the default behaviour of the IMS Bridge is to copy the requester’s message id to the reply messages’ correlation id, it is advisable to define the reply queue with an index type of CORRELID, and perform the get by correlation id.

How does the IMS bridge work?

There are 2 components to the IMS Bridge:

1. Putting messages from IBM MQ into IMS.
2. IMS putting reply messages back to MQ.

Putting messages from IBM MQ into IMS

For each IMS Bridge queue there is a task running in the queue manager. This task gets the message from the MQ queue and puts them into IMS via XCF. The task is effectively issuing an MQGET followed by a put to IMS and then commit.

If the messages are being put to this queue at a high rate, i.e. many applications putting to the queue concurrently, the task may not be able to keep up, resulting in increased queue depths.

When using a shared queue, each additional queue manager often will also have a task per IMS Bridge queue, and will be able to get messages from the queue and send them to IMS.

IMS putting reply messages to IBM MQ

IMS notifies the queue manager that a reply is available and MQ schedules an SRB to process this message. This SRB essentially does an MQOPEN, MQPUT of the reply and an MQCLOSE. If there are multiple replies coming back from IMS, then multiple SRBs can be scheduled and provided there are sufficient processors on the image, these can be run in parallel.

When using shared IMS Bridge queues and multiple queue managers are connected to the IMS Bridge, IMS will usually, but not always, send the reply back to the queue manager that sent the original request.

When an application puts a message to a shared IMS Bridge queue, the queue manager that the application is connected to will not necessarily be the same queue manager that sends the request to IMS. IMS will always put the reply message to the queue manager that put the original message. As a result, this reply message needs to be made available to the original application. By default, IGQ or the mover is used to send the message to the original system.

Using the queue manager option **SQQMNAME(IGNORE)** resolves the shared queue directly to the shared reply queue rather than to any particular queue manager (which would require the message to be moved).

Tuning the IMS subsystem

The IMS subsystem has been configured as described below:

- Checkpoint frequency has been adjusted so that checkpoints are not taken more than once every 10 to 20 minutes. This is controlled using the CPLOG keyword on the IMSCTF system definition macro. Supported values are 1000 to 16,000,000 (default 500,000). To override, modify the DFSPBxxx member of the PROCLIB DD, e.g. “CPLOG=16M”.
- The IMS subsystem has the QBUF attribute set to 256. When the QBUF value was less than the number of MPRs started, there was a significant degradation in throughput.
- Ensure the primary and secondary online logs for the IMS subsystem are large enough to avoid constant log switching and also to avoid being affected by the IMS archive job. Logs have been defined at 1500 cylinders each.
- Only define shared queues to the IMS storage class when they are needed. A fix was applied for PK14315 that wakes up unused IMS Bridge queues every 10 seconds. This is not a large overhead but if there are 100 shared queues defined with the IMS bridge storage class that are not actively being used, there is a small degradation in performance (around 1%).
- Check the IMS attribute QBUF. The IMS trace report provides a field “NUMBER OF WAITS BECAUSE NO BUFFER AVAILABLE”. When this is non-zero, this may be a hint that there is a lack of buffers.
- Check the IMS attribute PSBW. When reviewing some IMS workloads, it was observed than not all of the available MPRs were processing workload. This was because there was insufficient storage set aside to run all of the MPRs concurrently.
- Increase the size of the online datasets. Our default sizes of the DFSOLP* and DFSOLS* datasets meant that they were switching frequently. By increasing them from 50 to 1500 cylinders we reduced the frequency of switching.
- Increase the number of online datasets. When increased throughput occurs, the IMS archive jobs were attempting to process multiple logs in each step. We reached a point where no logs were available. By increasing the number of logs, we were able to prevent waiting for active logs to become available.

- The use of zHPF should be considered in the IMS environment as IMS always logs to disk. In our measurements we saw up to a 20% improvement in throughput.
- A single IMS transaction type defined INQUIRY(YES,NORECOV) for use with non-persistent messages.
- A single IMS transaction type defined INQUIRY(NO,RECOVER) for use with persistent messages.
- Both IMS transaction types are defined with
 - SCHDTYP=PARALLEL
 - PARLIM=0
 - WFI=Y

This will allow the IMS transactions to run concurrently on multiple message processing regions, removing a serialization bottleneck.

Note: Using the command “/DIS TRAN *tranName*” will show the value for “PARLM” – and NONE is not the same as 0. NONE means do not allow multiple instances of the transaction.

The message processing regions (MPRs) are started using the IMS performance related options¹ including:

- **DBLDL=<null>** which minimizes the cost of program loading by increasing program directory entries maintained in the MPR. This reduces I/O to program library to obtain the direct address of the program. Default is 20.
- **PRLD=TS** results in PROCLIB DD being searched for member DFSMPLTS. This contains a list of the recommended preloaded MQ modules plus the IMS transactions to be run e.g.

```
CSQACLST, CSQAMLST, CSQAPRH, CSQAVICM, CSQFSALM, CSQQDEFV,
CSQQCONN, CSQQDISC, CSQQTERM, CSQQINIT, CSQQBACK, CSQQCMMT,
CSQQESMT, CSQQPREP, CSQQTTHD, CSQQWAIT, CSQQNORM, CSQQSSOF,
CSQQSSON, CSQQRESV, CSQQSNOP, CSQQCMND, CSQQCVER,
CSQQTMID, CSQQTRGI, CSQBAPPI, IB02INQ, IB02INR
```

- **PWFI =Y** (pseudo wait-for-input) which can potentially reduce CPU time by eliminating the termination and re-scheduling of resources

NOTE: WFI=Y (Wait-For-Input) will keep the program loaded and ready for input. This reduces program start costs but will result in the MPR being dedicated to this transaction. The benefits of WFI=Y are seen when the workload driving the IMS is low and there would be frequent program starts, for example when running with WFI=N and using only 1 batch requester to drive workload using a single shared queue, there were 75 transactions per second. By specifying WFI=Y, the same batch requester was able to drive workload at 880 transactions per second.

When the driving the workload harder, the queue depth for the TPIPE typically is greater than 0 so when the IMS transaction issues a “GU” to get the next message, it is successful. This means that the transaction does not end and have to be restarted for subsequent messages and the MPR does not have to be dedicated to this particular transaction.

¹ These options are discussed at
http://publib.boulder.ibm.com/infocenter/dzichelp/v2r2/topic/com.ibm.ims12.doc.sag/system_admin/ims_tune_imsoptions.htm

Use of commit mode

The choice of IMS commit mode specified on the MQIIH structure can affect the performance of the IMS Bridge. Whether to use “Commit-Then-Send” (commit mode 0) or “Send-Then-Commit” (commit mode 1) is dependent on a number of factors, for example, if the application is putting a persistent message (i.e. an “important” message) it may be beneficial to use “Send-Then-Commit” (commit mode 1) – where the IMS message is not committed until the transaction completes. This will ensure that in the event of a failure, the transaction will either have completed successfully or will not have committed the work.

The flows involved for these commit modes are shown below:

Commit Mode 0 (Commit-Then-Send)

1. **IMS Bridge** puts message to TPIPE
2. **IMS** acknowledges
3. **MPR** runs application that issues GU + ISRT, then issues syncpoint
4. **IMS** output is enqueued to TPIPE
5. **MPR** transaction completes
6. **IMS** output sent (with response requested)
7. **MQ** acknowledges
8. **IMS** output de-queued

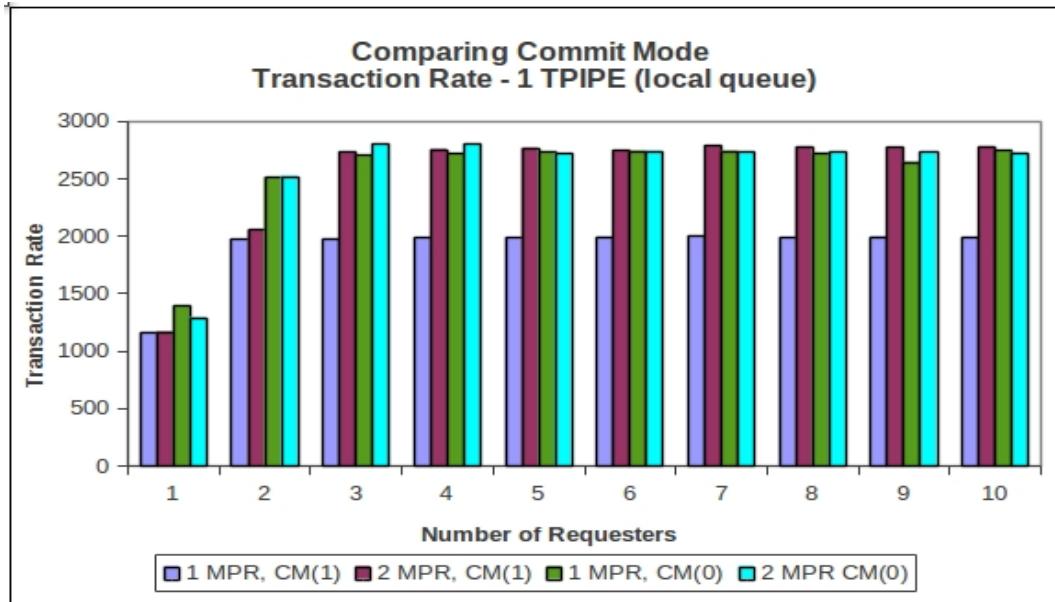
Commit Mode 1 (Send-Then-Commit)

1. **IMS Bridge** puts message to TPIPE
2. **MPR** runs application that issues GU + ISRT
3. **MPR** starts syncpoint
4. **IMS** output is sent to TPIPE, no response requested
5. **IMS** confirms commit, and completes the syncpoint
6. **MPR** transaction completes

For commit mode 0 (CM0), the message processing region (MPR) is able to process the next message before IMS sends the response to the MQ queue manager.

For commit mode 1 (CM1) case, the MPR is only available to process the next message when the transaction completes – i.e. step 6, which is after IMS has sent the output. This means the MPR is involved in each transaction for longer and this may mean additional MPRs are required sooner.

The following chart compares the transaction rate when increasing the number of batch requesters putting 1K non-persistent messages to a single local queue that has been defined with the IMS Bridge storage class. The commit mode is varied to show how CM1 can restrict the transaction rate when there are insufficient message processing regions.



Notes on chart:

- In none of the above measurements is the machine running at 100% capacity.
- When there is only 1 MPR servicing the workload, a peak transaction rate of 2000/second is seen for the applications using CM1. By contrast, when running with 1 MPR and CM0, the peak transaction rate is 2750/second.
- By adding a second MPR for the CM1 workload, the peak transaction rate is able to track the CM0 workload.
- The chart also shows that in this environment², adding a second MPR for the CM0 workload gave little benefit.

² These measurements were run on a 2084-303 and the machine was running at approximately 90% of capacity.

Understanding limitations of the IMS bridge

There are a number of components involved when using the IMS bridge that need to be considered when attempting to achieve the best transaction rate for an application.

Consider the scenario where the achieved transaction rate does not match the required rate. All of the following components could be affecting the transaction rate:

- **IMS**

- Are the message processing regions running at capacity? There may not be sufficient message processing regions available.
- Can the transaction process multiple requests? When the transaction finishes without checking for subsequent requests, there can be a significant effect on the transaction rate if the next transaction has to be loaded.

- **IBM MQ**

- Is there a build up of messages on the IMS Bridge queues? This may be for a number of reasons including:
- Either the IMS subsystem or message processing regions are not being given sufficient priority.
- The MQ task is unable to get the messages fast enough. Using more IMS Bridge queues may help – alternatively if using shared queues, additional queue managers in the queue sharing group may help.
- Is there a build-up of messages on the reply-to queue? Is the reply-to queue indexed appropriately, e.g. if getting using the CORRELID, verify that the queue is indexed by CORRELID.

- **CPU**

- Is the machine running at peak capacity? A quick indication can be seen from the “Active Users” panel in SDSF – e.g. via “S.DA”. For a longer term view, the “LPAR Cluster Report” report from RMF can be used to determine whether the machine is running at or close to 100% capacity.

L P A R C L U S T E R R E P O R T ^a								
z/OS V1R9		SYSTEM ID MV25						
RPT VERSION V1R9 RMF TIME 22.12.13								
----- WEIGHTING STATISTICS ----- ----- PROCESSOR STATISTICS -----								
CLUSTER	PARTITION	SYSTEM	INIT	MIN	MAX	DEFINED	ACTUAL	LBUSY PBUSY
PLEX3	MVS2A	MV2A	DED			3	3	99.97 9.67
	MVS2B	MV2B	DED			5	3	97.52 9.44
	MVS25	MV25	DED			3	3	100.0 9.68

^a Some detail has been removed from the LPAR cluster report shown since the system is using dedicated processors.

- **Coupling Facility**

- Is the coupling facility running at an optimum level – use of the RMF III reports will show how utilised the coupling facility CPUs are.

- What type of links between the z/OS image and the coupling facility are in place – are they ICP links or are they a physical cable?
- Are the coupling facility structures duplexed and how far apart are they located?
- For more information on coupling facility considerations, refer to the “[Coupling Facility](#)” chapter.

- **XCF**

- Since the IMS Bridge function in the queue manager uses XCF to pass requests to the IMS, there will be a requirement to ensure the XCF address space is running optimally. The XCF address space allocates the Couple Datasets (XCF, Logger, CFRM, WLM, ARM and OMVS). The document “[Parallel Sysplex Performance: XCF Performance Considerations](#)”, gives guidelines on tuning XCF which may be of benefit to improving the IMS Bridge throughput.

The following sections aim to help to identify where the constraints may lie by giving guidance on how to determine:

- When the constraint is due to the message processing region.
- When the constraint is due to the IBM MQ task that puts the message onto the IMS Bridge queue.

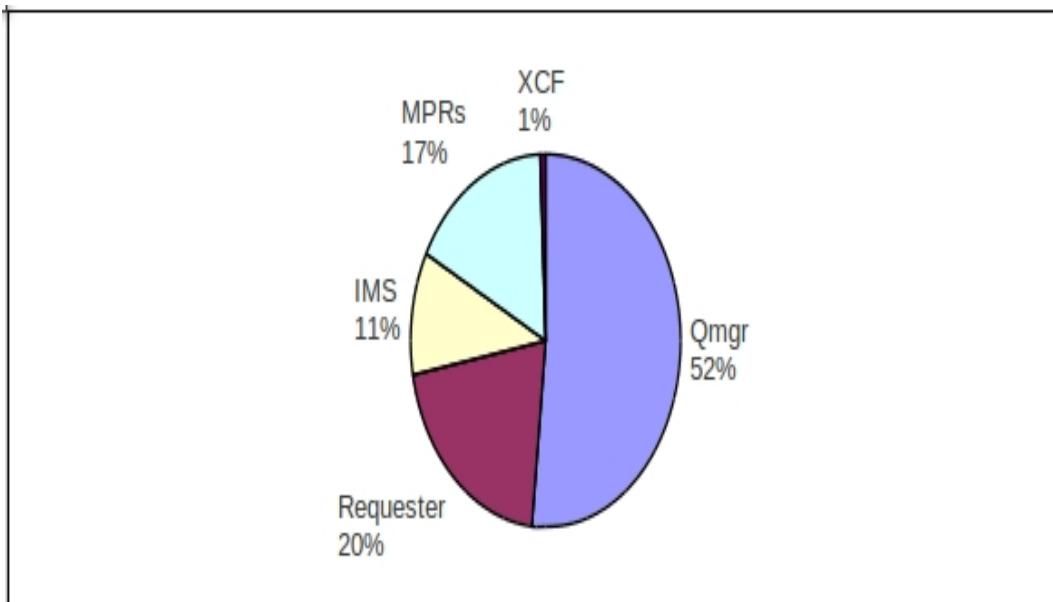
When do I need more message processing regions?

By providing a message processing region (MPR) that has the IMS transaction to be run pre-loaded and in a wait-for-input (WFI), there is a significant reduction in the time taken to schedule the IMS transaction.

The following trace examples are taken when the following environment is used:

- A single 2084-303 image
- A single queue manager in a queue sharing group
- A single IMS control region
- 2 MPRs configured as detailed at the top of this section, i.e. the transactions being run are set to be WFI=Y.
- 6 batch applications each putting to a single IMS Bridge shared queue and getting a reply message using the CORRELID from a corresponding reply-to shared queue that is indexed by CORRELID.
- Commit Mode 1 – “Send then Commit” was specified in the MQIIH data structure.
- The machine was seen to be running at 92% capacity and the overall transaction rate was 1803 transactions per second.

The following shows where the work was done in achieving the throughput mentioned above.



To identify whether the workload was constrained by lack of MPRs, the IMS trace function was enabled using “[/TRACE SET ON MONITOR ALL INTERVAL 60](#)” and the IMS program DFSUTR20 was used to print the records e.g.

```
//JOBLIB DD DISP=SHR,DSN=IMS.VXX.DBDC.SDFSRESL
//          EXEC PGM=DFSUTR20,REGION=512K
//SYSPRINT DD SYSOUT=*
//SYSUT1 DD DISP=SHR,DSN=IMSDATA.IMXX.IMS MON
//ANALYSIS DD *
DLI
/*
```

This produced a number of useful reports³ including:

1. Run Profile
2. Call Summary
3. Region Summary Report
4. Region IWAIT (IMS Wait)
5. Program Summary
6. Program I/O

Understanding the trace reports - run profile

IMS MONITOR *** RUN PROFILE ***
TRACE ELAPSED TIME IN SECONDS.....59.9
TOTAL NUMBER OF MESSAGES DEQUEUED.....107692
TOTAL NUMBER OF SCHEDULES.....2
NUMBER OF TRANSACTIONS PER SECOND.....1794.8
TOTAL NUMBER OF DL/I CALLS ISSUED.....215380
NUMBER OF DL/I CALLS PER TRANSACTION.....1.9
NUMBER OF OSAM BUFFER POOL I/O'S.....0, 0.0 PER TRANSACTION
NUMBER OF MESSAGE QUEUE POOL I/O'S.....115, 0.0 PER TRANSACTION
NUMBER OF FORMAT BUFFER POOL I/O'S.....0, 0.0 PER TRANSACTION

Notes on ‘run profile’ report

- The number of “messages dequeued” is the number of scheduled PSBs.
- The number of schedules (2) indicates that only 2 transactions were started during the monitoring period – this is as expected since the transactions are defined with WFI=Y and there were 2 MPRs started
- The “transactions per second” is the number of PSB schedules per second, so in the above example there are 1794.8 PSBs being scheduled each second for the lifetime of the monitoring period (59.9 seconds). This is close to the previously reported transaction rate of 1803 transactions/second – which was calculated using figures output from the application programs.

³ Information on these reports can be found at
http://publib.boulder.ibm.com/infocenter/dzichelp/v2r2/topic/com.ibm.ims11.doc.sag/ims_reports/ims_imsmmonrpt.htm

Understanding the trace reports – call summary

IMS MONITOR *** CALL SUMMARY ***						
	CALL	LEV	STAT	CALLS	IWAITS	IWAITS/
PSB NAME PCB NAME FUNC	NO. SEGMENT	CODE		CALL	MEAN	.NOT IWAIT TIME..
IB02INQ I/O PCB ISRT (...)	107691			0	0.00	MEAN
GU (...)	107689			10	0.00	MAXIMUM
I/O PCB SUBTOTAL	215380			10	0.00	11
PSB TOTAL	215380			10	0.00	2640
					349	28874
						686
						28874
						349

Notes on ‘call summary’ report

- The “Call Summary” report shows how simple the IMS transaction is – it issues a “GU” call to get the MQ message and issues a “ISRT” to send the reply message.
- The number of IWAITS (IMS waits) for the GU function is 10, which since there were 107,691 calls indicates that the MPR was being driven hard enough such that it was not waiting for work.

Understanding the trace reports – region summary report

		Elapsed Time.....			Not Iwait Time(Elapsed-Iwait)		
		OCCURRENCES	TOTAL	MEAN	MAXIMUM	TOTAL	MEAN
SCHEDULING AND TERMINATION							
SCHEDULE TO FIRST CALL							
**REGION	1	1	3235	3235	3235		
**REGION	4	1	1007	1007	1007		
**TOTALS		2	4242		2121		
ELAPSED EXECUTION							
**REGION	1	1	38219948	38219948	38219948		
**REGION	4	1	38117765	38117765	38117765		
**TOTALS		2	76337713	38168856			
DL/I CALLS							IWT/CALL
**REGION	1	107821	37679783	349	27264	37668306	349 0.00
**REGION	4	107559	37571817	349	28874	37568048	349 0.00
**TOTALS		215380	75251600	349		75236354	349 0.00
IDLE FOR INTENT		NONE					
CHECKPOINT		6	143571	23928	29396	143571	23928 29396
REGION OCCUPANCY							
**REGION	1		63.7%				
**REGION	4		63.5%				

Notes on ‘call summary’ report

- The “Checkpoint” section indicates there were 6 checkpoints taken during the monitoring period (as seen below). Ideally the checkpoint frequency will be between 10 and 20 minutes, so in the above example, we are taking checkpoints too frequently. Changing the IMS “CPLOG” value should cause the checkpoint frequency to change.
- The “Region Occupancy” section indicates the ratio of the elapsed time when the thread is active to the trace interval. This suggests that the MPRs are running at 63% of capacity and therefore it should be possible to drive this workload harder than in this example. It also suggests that adding MPRs would not necessarily improve the throughput for this scenario.

IMS Control Region issuing checkpoints whilst monitoring running

12.24.54 STC00997	DFS2212I DC MONITOR STARTED	IM9A
12.25.03 STC00997	DFS2716I NO MSDBS FOUND - NO MSDB CHECKPOINT TAKEN	IM9A
12.25.03 STC00997	DFS994I *CHKPT 08296/122503**SIMPLE*	IM9A
12.25.03 STC00997	DFS3499I ACTIVE DDNAMES: MODBLKSA IMSACBA FORMATA MODSTAT ID: 0	IM9A
12.25.03 STC00997	DFS3804I LATEST RESTART CHKPT: 08296/122436, LATEST BUILDQ CHKPRT: 08296/120523	IM9A
12.25.13 STC00997	DFS2716I NO MSDBS FOUND - NO MSDB CHECKPOINT TAKEN	IM9A
12.25.13 STC00997	DFS994I *CHKPT 08296/122513**SIMPLE*	IM9A
12.25.13 STC00997	DFS3499I ACTIVE DDNAMES: MODBLKSA IMSACBA FORMATA MODSTAT ID: 0	IM9A
12.25.13 STC00997	DFS3804I LATEST RESTART CHKPT: 08296/122503, LATEST BUILDQ CHKPRT: 08296/120523	IM9A
12.25.22 STC00997	DFS2716I NO MSDBS FOUND - NO MSDB CHECKPOINT TAKEN	IM9A
12.25.22 STC00997	DFS994I *CHKPT 08296/122522**SIMPLE*	IM9A
12.25.22 STC00997	DFS3499I ACTIVE DDNAMES: MODBLKSA IMSACBA FORMATA MODSTAT ID: 0	IM9A
12.25.22 STC00997	DFS3804I LATEST RESTART CHKPT: 08296/122513, LATEST BUILDQ CHKPRT: 08296/120523	IM9A
12.25.31 STC00997	DFS2716I NO MSDBS FOUND - NO MSDB CHECKPOINT TAKEN	IM9A
12.25.31 STC00997	DFS994I *CHKPT 08296/122531**SIMPLE*	IM9A
12.25.31 STC00997	DFS3499I ACTIVE DDNAMES: MODBLKSA IMSACBA FORMATA MODSTAT ID: 0	IM9A
12.25.31 STC00997	DFS3804I LATEST RESTART CHKPT: 08296/122522, LATEST BUILDQ CHKPRT: 08296/120523	IM9A
12.25.41 STC00997	DFS2716I NO MSDBS FOUND - NO MSDB CHECKPOINT TAKEN	IM9A
12.25.41 STC00997	DFS994I *CHKPT 08296/122541**SIMPLE*	IM9A
12.25.41 STC00997	DFS3499I ACTIVE DDNAMES: MODBLKSA IMSACBA FORMATA MODSTAT ID: 0	IM9A
12.25.41 STC00997	DFS3804I LATEST RESTART CHKPT: 08296/122531, LATEST BUILDQ CHKPRT: 08296/120523	IM9A
12.25.50 STC00997	DFS2716I NO MSDBS FOUND - NO MSDB CHECKPOINT TAKEN	IM9A
12.25.50 STC00997	DFS994I *CHKPT 08296/122550**SIMPLE*	IM9A
12.25.50 STC00997	DFS3499I ACTIVE DDNAMES: MODBLKSA IMSACBA FORMATA MODSTAT ID: 0	IM9A
12.25.50 STC00997	DFS3804I LATEST RESTART CHKPT: 08296/122541, LATEST BUILDQ CHKPRT: 08296/120523	IM9A
12.25.54 STC00997	DFS2213I DC MONITOR STOPPED - (TIME INTERVAL ELAPSED) IM9A	

Notes: This extract confirms that there were 6 checkpoints taken during the period of monitoring as seen in the previous “Region Summary Report”.

Understanding the Trace reports – Region IWAIT Report

There will be a “Region IWAIT” report for each region, so in this example there will be 2 reports.

IMS MONITOR *** REGION IWAIT ***						
				WAIT TIME.....	MAXIMUM	FUNCTION MODULE
**REGION	1 OCCURRENCES	TOTAL	MEAN			
SCHEDULING + TERMINATION						
...SUB-TOTAL...						
...TOTAL..:						
DL/I CALLS	4	11477	2869	9734	DD=LGMSG	QMG
...TOTAL..:	4	11477	2869			
CHECKPOINT						
...TOTAL...						

IMS MONITOR *** REGION IWAIT ***						
				WAIT TIME.....	MAXIMUM	FUNCTION MODULE
**REGION	4 OCCURRENCES	TOTAL	MEAN			
SCHEDULING + TERMINATION						
...SUB-TOTAL...						
...TOTAL..:						
DL/I CALLS	6	3769	628	995	DD=LGMSG	QMG
...TOTAL..:	6	3769	628			
CHECKPOINT						
...TOTAL...						

Notes: These reports suggest that region 1 is waiting on average 4.5 times longer than region 4 on the few occasions that the regions are in a wait (a total of 10 times). It also suggests that all of the waits were for the LGMSG dataset.

Understanding the trace reports – Program Summary Report

IMS MONITOR *** PROGRAM SUMMARY ***							
PSBNAME	NO. SCHEDS.	TRANS. DEQ.	CALLS /TRAN	I/O IWAITS /CALL	I/O DEQD. /SCH.	CPU TIME /SCHED.	. ELAPSED TIME 1ST CALL /SCHED. /TRANS.
TB02INQ	2	107692	215380	1.9	10 0.0 3846.0	26	38168856 2121 708
**TOTALS	2	107692	215380	1.9	10 0.0 3846.0	26	38168856 2121 708

Notes: This report confirms that there were 10 waits for I/O (for DD=LGMSG). It also tells us that in the monitoring period, 107,692 transactions were run over the 2 message processing regions.

Understanding the trace reports – Program I/O Report

IMS MONITOR *** PROGRAM I/O ***						
		IWAITS	TOTAL	MEAN	MAXIMUM	DDN/FUNC MODULE
PSBNAME	PCB NAME					
IB02INQ	I/O PCB	50600	21753542	429	28525	**W F I
		50379	21858044	433	23535	**W F I
		10	15246	1524	9734	LGMSG QMG
PCB TOTAL		10	15246	1524		
PSB TOTAL		10	15246	1524		
GRAND TOTAL		10	15246	1524		

Notes: This report suggests that the IMS transaction “IB02INQ” has had a significant number of IMS waits (100,979) with an average time of 429-433 microseconds. This again suggests that there are sufficient MPRs to support the MQ workload, or conversely that there was insufficient workload to drive the MPR at capacity.

As an example of when additional MPRs may be required, the following 2 reports were taken when running with 16 batch applications using the same TPIPE.

16 Batch Applications, 1 PIPE, 4 MPRs

IMS MONITOR *** PROGRAM I/O ***						
PSBNAME	PCB NAME	IWAITS	TOTAL	MEAN	MAXIMUM	DDN/FUNC MODULE
IB02INQ	I/O PCB	41	24830	605	1628	**W F I
		41	33346	813	3314	**W F I
		43	25763	599	2063	**W F I
		27	12985	480	1931	**W F I
		8	15786	1973	10010	LGMMSG QMG
PCB TOTAL		8	15786	1973		
PSB TOTAL		8	15786	1973		
GRAND TOTAL		8	15786	1973		

16 Batch Applications, 1 PIPE, 5 MPRs

IMS MONITOR *** PROGRAM I/O ***						
PSBNAME	PCB NAME	IWAITS	TOTAL	MEAN	MAXIMUM	DDN/FUNC MODULE
IB02INQ	I/O PCB	1593	900430	565	5323	**W F I
		1530	853962	558	3391	**W F I
		1525	886910	581	8103	**W F I
		1595	887466	556	5685	**W F I
		1613	899249	557	4565	**W F I
		10	6843	684	1124	LGMMSG QMG
PCB TOTAL		10	6843	684		
PSB TOTAL		10	6843	684		
GRAND TOTAL		10	6843	684		

Notes: In both cases, the number of IMS waits is significantly less than in the original example. The numbers in blue correspond to the number of message processing regions active.

When there are 4 MPRs servicing the MQ workload, a very low number of IWaits can be seen. This would indicate that the MPRs are nearly always busy, and adding additional MPRs may be of benefit. There is also a small number of waits (8) on the LGMMSG dataset.

When there are 5 MPRs servicing the workload, the number of IWaits increases which suggests there is spare capacity.

To confirm this, a look at the “Region Occupancy” section of the “Region Summary” report, shows that for 4 MPRs, each region was running at 99.7% whereas when running with 5 MPRs, the regions ran at 98.3% - again showing there is some, but not much, spare capacity.

When do I need more TPIPEs?

At some point, the task running in the queue manager that is getting messages from the request queue and putting to IMS cannot run any faster. At this point, additional throughput may be achieved by using multiple IMS Bridge queues (which will each have a separate queue manager task).

Alternatively, if shared queues are in use, the addition of another queue manager in the QSG will provide another task to get the message from the queue and pass to IMS.

To determine whether more TPIPEs will benefit the throughput, the IMS region will again need to be monitored to determine whether the MPRs are working efficiently. In addition, the MQ queues need to be checked to see if a backlog is building either on the request or the reply queue.

This example is based on 2 sets of measurements:

Both measurements used local IMS Bridge queues with the workload running on LPAR 1 (rated as a 2084-303).

Commit Mode	0 Commit-Then-Send	1 Send-Then-Commit
MPR	2	2
TPIPEs	1	1
Requester Tasks	6	6
Persistent Messages	No	No
Transaction Rate	2700 / sec	2747 / sec
CPU Utilisation	82.5%	87%
Cost / Transaction	917 microseconds	950 microseconds

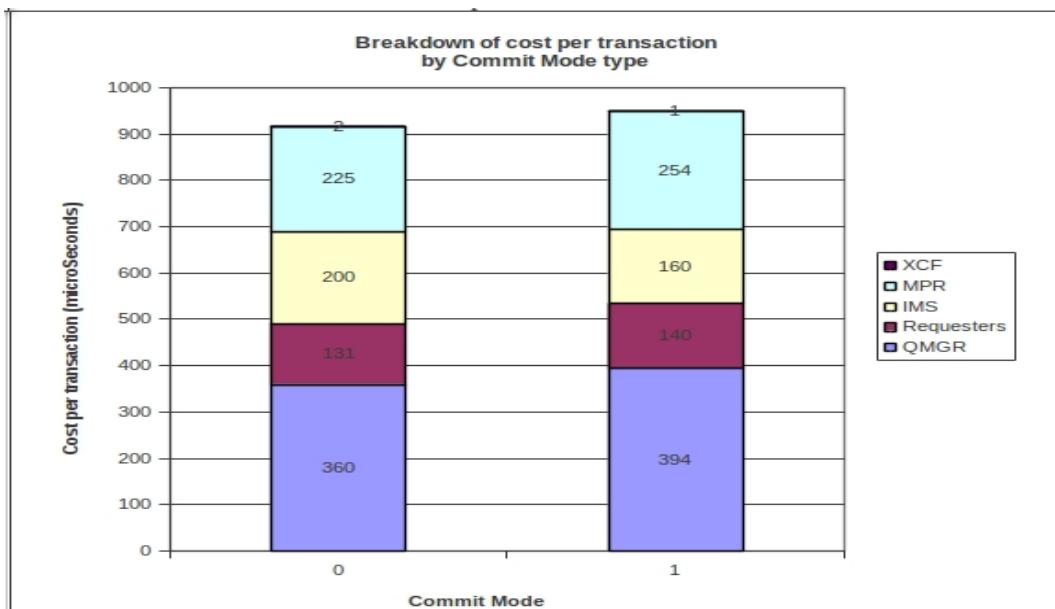
What information can we get from the above table?

- The workload is not CPU-constrained.
- Whilst CM1 is achieving a higher transaction rate, the cost per transaction is also higher than for CM0.

The following chart shows where the costs are incurred in these 2 measurements.

Compared to commit mode 0 “Commit-Then-Send”, the commit mode 1 “Send-Then-Commit” measurements show:

- 10% increase in the cost of the queue manager processing the transaction over commit mode 0 “Commit-Then-Send”
- 13% increase in the cost of the MPR processing the transaction.
- 20% decrease in the cost to the IMS control region
- A 3.5% overall increase in cost per transaction.



Looking at the trace reports for these 2 measurements shows the Region Occupancy for the MPRs at:

- 31.2% and 29.9% for the commit mode 0 “Commit-Then-Send” measurement.
- 72.3% and 72.3% for the commit mode 1 “Send-Then-Commit” measurement.

Looking at the “Program I/O” report for the Commit Mode 0 measurement:

IMS MONITOR *** PROGRAM I/O ***						
.....IWAIT TIME.....						
PSBNAME	PCB NAME	IWAITS	TOTAL	MEAN	MAXIMUM	DDN/FUNC ...
IB02INQ	I/O PCB	82718	41191904	497	192534	**W F I
		79081	42015547	531	168595	**W F I
		52	111728	2148	25744	LGMSG

This above extract shows that there are a significant number of IMS waits for each MPR, average 0.5 milliseconds.

Similarly the “Program I/O” report for Commit Mode 1 shows:

IMS MONITOR *** PROGRAM I/O ***						
.....IWAIT TIME.....						
PSBNAME	PCB NAME	IWAITS	TOTAL	MEAN	MAXIMUM	DDN/FUNC ...
IB02INQ	I/O PCB	79882	16582118	207	29985	**W F I
		79855	16592048	207	29200	**W F I
		10	17574	1757	13233	LGMSG

This extract shows that there are a significant number of IMS waits for each MPR, average 0.2 milliseconds.

This suggests that the MPRs have the capacity to be driven at higher transaction rate.

Since we also know that there is more capacity available on the LPAR, something else is causing the constraint.

By issuing the queue manager command “RESET QSTATS” against the request and the reply queues, firstly to reset and then secondly (a period of time later) to review, it was seen that the request queue has a HIQDEPTH of 6 for both commit modes. The reply queue had a HIQDEPTH of 1 for commit mode 0 and 4 for commit mode 1.

That the request queue had a HIQDEPTH of 6 suggests that the queue manager task that gets the message from the request queue and put to the IMS Bridge is not able to keep pace with the workload.

In the case of the reply queue, the values for HIQDEPTH show that for commit mode 0, the replies are being gotten by the batch applications as quickly as the messages are put.

The tests were re-run using 2 TPIPEs, to see if allowing the queue manager a second task to get messages from the request queues will help drive the workload at a higher rate.

Commit Mode	0 Commit-Then-Send	1 Send-Then-Commit
MPR	2	2
TPIPEs	2	2
Requester Tasks	6	6
Persistent Messages	No	No
Transaction Rate	2852 / sec	3017 / sec
CPU Utilisation	89.5%	92.57%
Cost / Transaction	941 microseconds	920 microseconds

Looking at the trace reports for these 2 measurements shows the Region Occupancy for the MPRs at:

- 33.6% and 34% for the Commit Mode 0 “Commit-Then-Send” measurement.
- 99.7% and 99.7% for the Commit Mode 1 “Send-Then-Commit” measurement.

Looking at the “Program I/O” report for the Commit Mode 0 (Commit-then-Send) measurement:

IMS MONITOR *** PROGRAM I/O ***						
.....IWAIT TIME.....						
PSBNAME	PCB NAME	IWAITS	TOTAL	MEAN	MAXIMUM	DDN/FUNC ...
IB02INQ	I/O PCB	85064	39500980	464	13979	**W F I
		84605	39736498	469	86560	**W F I
		82	167153	2038	37939	LGMSG

This shows a slight increase in the number of IMS waits (from 161,799 to 169,669) but the average time has also decreased slightly (from 500 microseconds to 467 microseconds).

For Commit Mode 1 (Send-then-Commit), there is a marked improvement –which can be seen in the “Program I/O” report following:

IMS MONITOR *** PROGRAM I/O ***						
.....IWAIT TIME.....						
PSBNAME	PCB NAME	IWAITS	TOTAL	MEAN	MAXIMUM	DDN/FUNC ...
IB02INQ	I/O PCB	713	166333	233	14037	**W F I
		693	158148	228	13302	**W F I
		16	48000	3000	14989	LGMSG

Compared to the previous run that used 1 TPIPE, the number of IMS waits has dropped significantly, from 159,737 to 1406, whilst the average wait is still approximately 0.2 milliseconds. This suggests that the workload is potentially constrained by the MPRs.

Checking the information reported by the “RESET QSTATS” command, for both commit mode 0 and commit mode 1, the HIQDEPTH is now 3 for each of the two IMS Bridge Queues and 2 for each of the reply queues.

In summary, for Commit Mode 0 there has been a 5.6% increase in the transaction rate simply by using a second TPIPE. The MPRs are not running at capacity, which suggests that using further TPIPEs will help drive the workload faster.

For Commit Mode 1, simply by using a second TPIPE, there has been 9.8% increase in the throughput. Since the MPRs are now nearing 100% occupancy, the next step would be to add a further MPR and re-evaluate.

IMS Bridge Throughput – Local Queues

The following section uses a standard configuration for measuring performance of the IMS Bridge queues as defined in the “[Initial Configuration](#)” section. The aim of these charts is to provide a comparison with other measurements such as “IMS Bridge Throughput – Shared Queue – Single Queue Manager” rather than showing the optimum throughput achieved on our system.

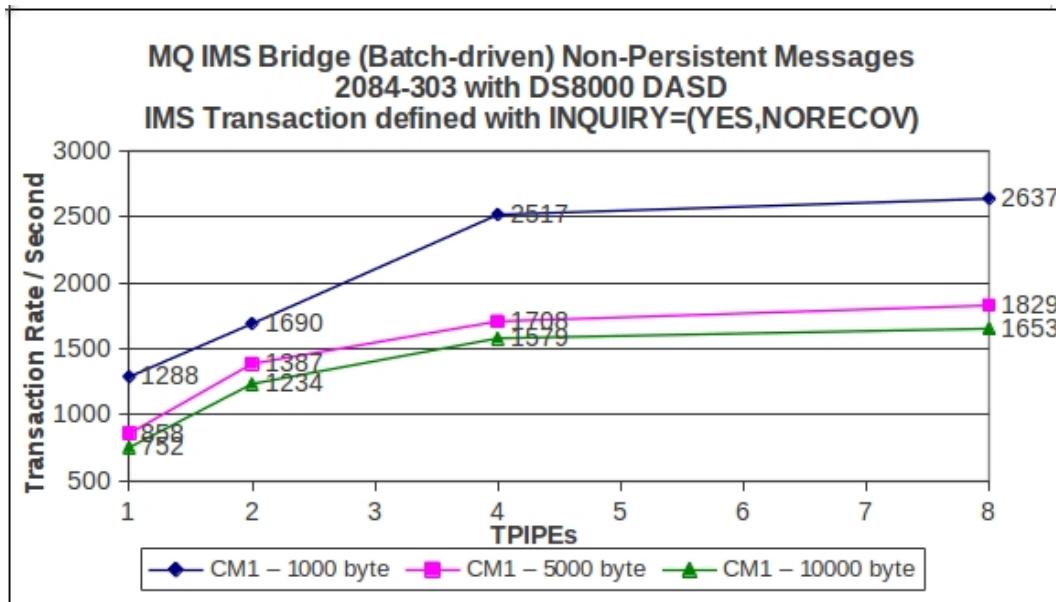
For these particular measurements, the system under test is configured as follows:

- The LPAR in use is a 2084-303
- 8 IMS Bridge local queues defined
- 8 corresponding reply-to queues that have been defined with an index type of CORRELID.
- The IMS region will have 4 message processing regions started with “wait-for-input”.
- The workload will be 8 batch requester tasks that put a message to only 1 of the 8 IMS Bridge queues and waits for a reply on the corresponding reply-to-queue.
- When only 1 TPIPE is being used, all 8 requesters will put to the same IMS Bridge queue and get from a common reply queue.
- When 8 TPIPEs are being used, each of the 8 requester tasks will put to a separate IMS Bridge queue and get from a corresponding reply-to queue.

NOTE: A transaction is defined as a batch task putting a message to an IMS Bridge queue and then getting a reply message from a corresponding reply-to queue (indexed by CORRELID) using CORRELID to get the message.

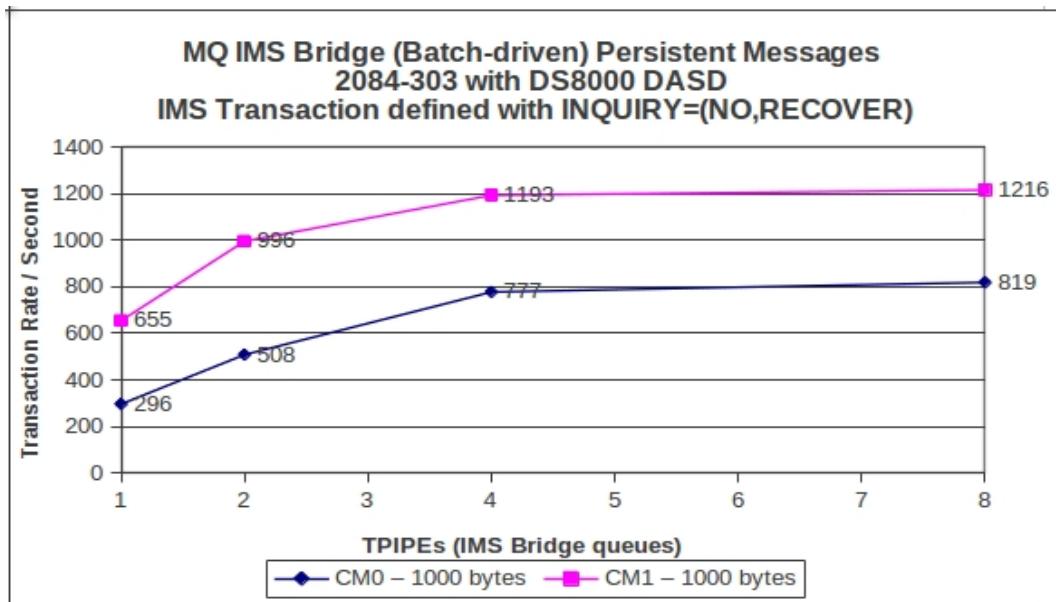
Since the queue manager will be on the same z/OS image as the IMS subsystem, the OTMA will be local which will provide a greater throughput capacity than a remote link.

Non-Persistent Message Throughput – Local queues



NOTE: The configuration for the preceding measurement saw the machine run at a peak of 60% of capacity. By following the guidelines set out previously, we were able to drive workload using 1KB non-persistent messages using 1 IMS Bridge queue supported by a single MPR at 2000 transactions / second, an increase of 35% and at close to 100% of the LPAR capacity.

Persistent Message Throughput – Local Queues



NOTE: The configuration for the preceding measurement saw the machine run at a peak of 50% of capacity and therefore it is possible to increase the throughput by following the instructions earlier in this chapter.

Commit mode 1 (Send-then-Commit) can be seen to be significantly out-performing the commit

mode 0 configuration when using persistent messages. This is because CM1 has less IMS logging than CM0.

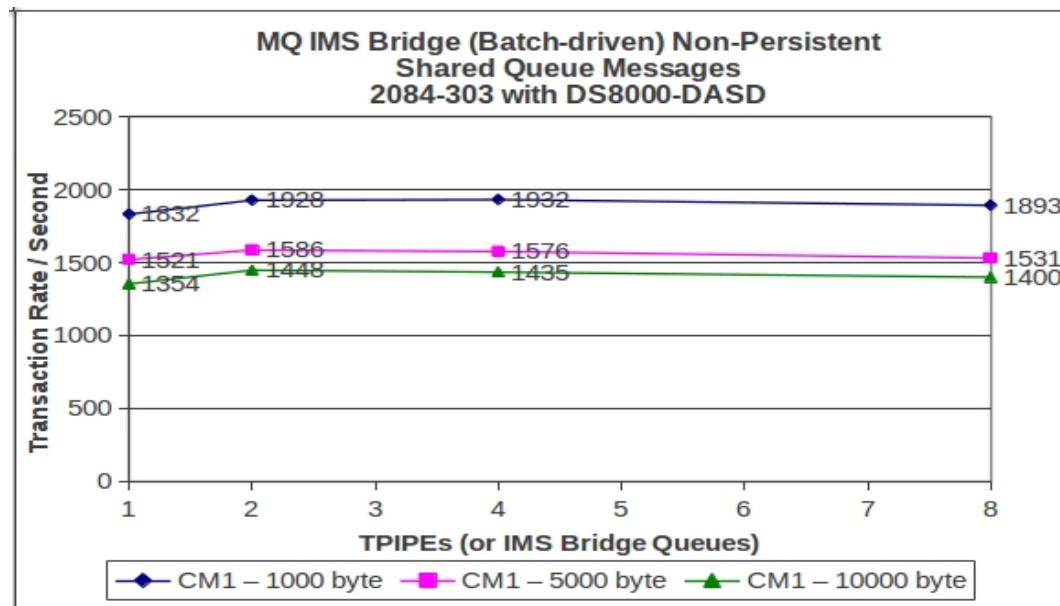
IMS Bridge Throughput – Shared Queue – Single Queue Manager

The following section uses a standard configuration for measuring performance of the IMS Bridge queues as defined in the “Initial Configuration” section. The aim of these charts is to provide a comparison with other measurements such as “IMS Bridge Throughput – Local Queues” rather than showing the optimum throughput achieved on our system.

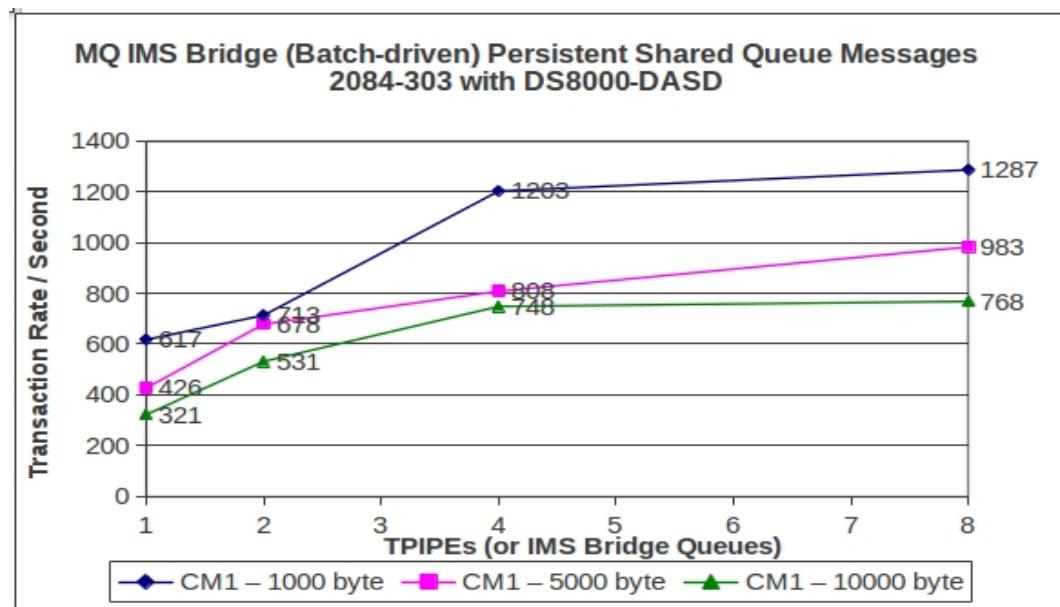
For these particular measurements, the system under test is configured as follows:

- The LPAR in use is a 2084-303.
- 8 IMS Bridge shared queues are defined.
- 8 corresponding reply-to shared queues that have been defined with an index type of COR-RELID.
- The IMS region will have 4 message processing regions started with “wait-for-input”.
- The workload will be 8 batch requester tasks that put a message to only 1 of the 8 IMS Bridge queues and waits for a reply on the corresponding reply-to queue.
 - When only 1 TPIPE is being used, all 8 requesters will put to the same IMS Bridge queue and get from a common reply queue.
 - When 8 TPipes are being used, each of the 8 requester tasks will put to a separate IMS Bridge queue and get from a corresponding reply-to queue.

Non-Persistent Message Throughput – Shared Queue



Persistent Message Throughput – Shared Queue



IMS Bridge Throughput using Remote Queue Managers

The measurements in this section use a different configuration to previous sections – rather than using 1 LPAR configured as a 2084-303, there will be 3 LPARs available, configured thus:

LPAR 1 2084-305 (5 CPUs)

Hosts the IMS subsystem,
8 message processing regions.

Hosts a queue manager that is part of queue sharing group (QSG).

LPAR 2 2084-303 (3 CPUs)

Hosts second queue manager in the QSG.

LPAR 3 2084-303 (3 CPUs)

Hosts third queue manager in the QSG.

Depending on the measurement, some of the queue managers in the QSG may be stopped.

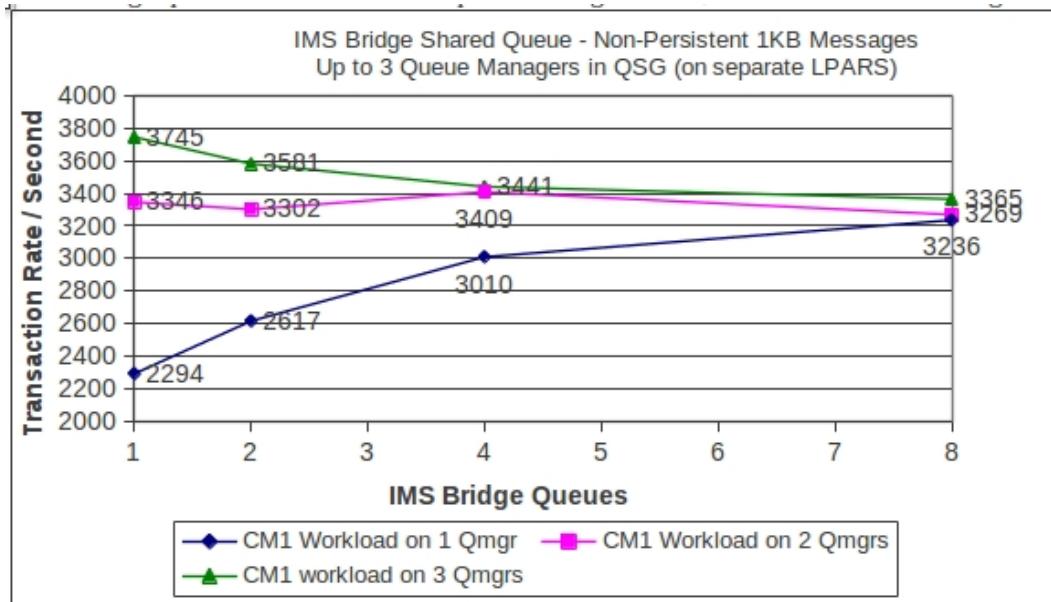
Workload in the form of batch requester tasks will be run on different LPARs depending on the measurement.

In the case where shared queue IMS Bridge queues are used, there is a TPIPE from each queue manager to IMS for every bridge queue. This means when there are 3 queue managers available, there will be 3 TPIPs per shared IMS Bridge queue. These TPIPs will race for the next message on each such shared queue. Thus the queue manager on LPAR 2 can MQGET a message that was created by the queue manager on LPAR 1 and send it to IMS over its OTMA link. When the response is returned (typically to the queue manager that put the message to IMS), the queue manager on LPAR 2 must resolve the destination reply-to queue to a specific queue.

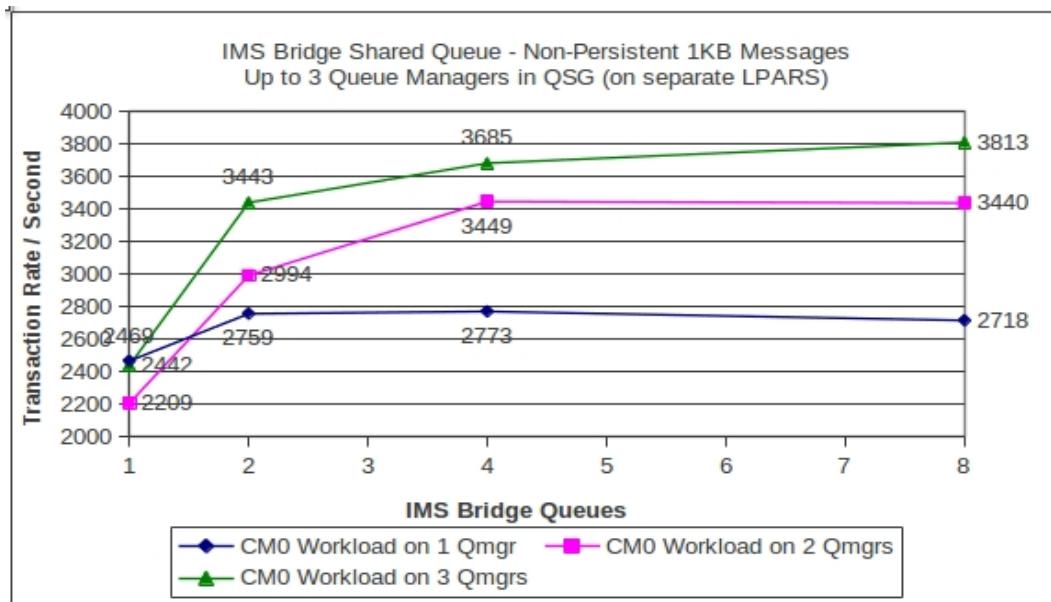
A queue manager with attribute `SQQMNAME(IGNORE)` resolves the reply-to-queue directly to the shared queue. If the `SQQMNAME(IGNORE)` attribute is not set, the message may be put to the dead letter queue with a reason code 2087 ‘Unknown Remote Queue Manager’.

Shared Queue – Non-Persistent Messages

The following chart shows the throughput achieved when the number of queue managers active are all running a workload using 16 batch requesters to drive a varying number of IMS Bridge queues. When there is 1 queue manager active, it is local to the IMS region.

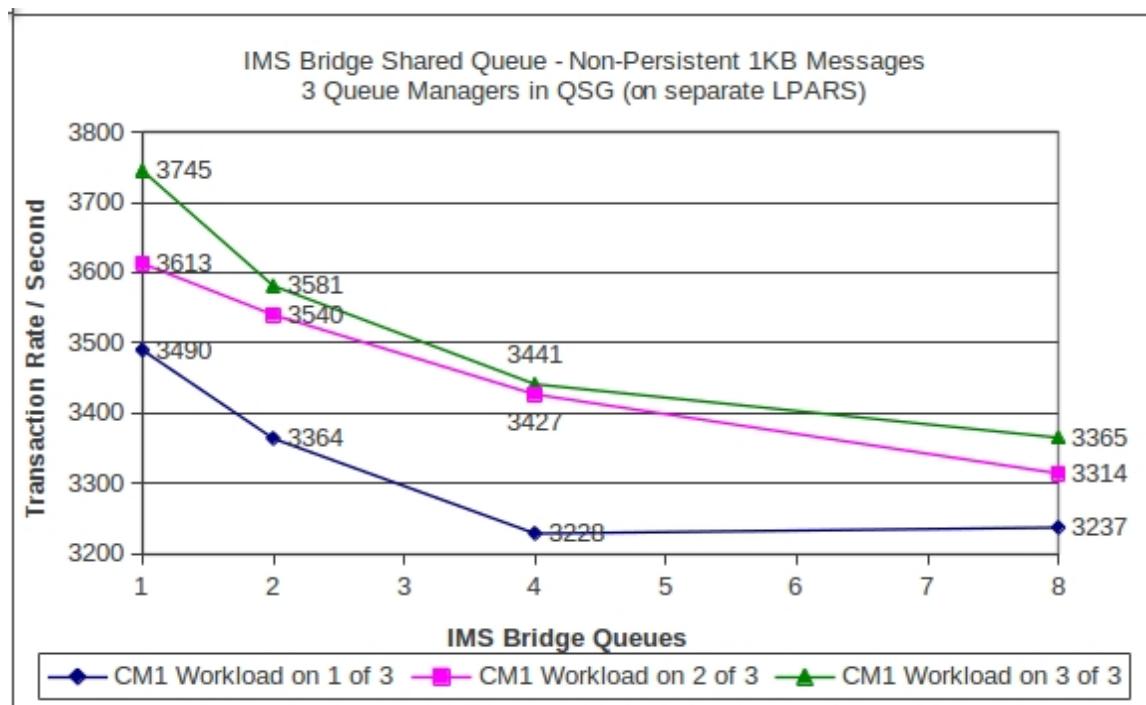


The following chart shows the same configuration as previously but using Commit Mode 0 (Commit-Then-Send).



In the following chart, all 3 queue managers are running on separate LPARs but the workload will be run on only 1, 2 or 3 of those queue managers.

When workload is run on any particular LPAR, there will be 16 batch requester tasks, i.e. when the workload runs on 2 LPARs, there will be a total of 32 batch requester tasks, and 48 batch requester tasks when running on 3 LPARs.

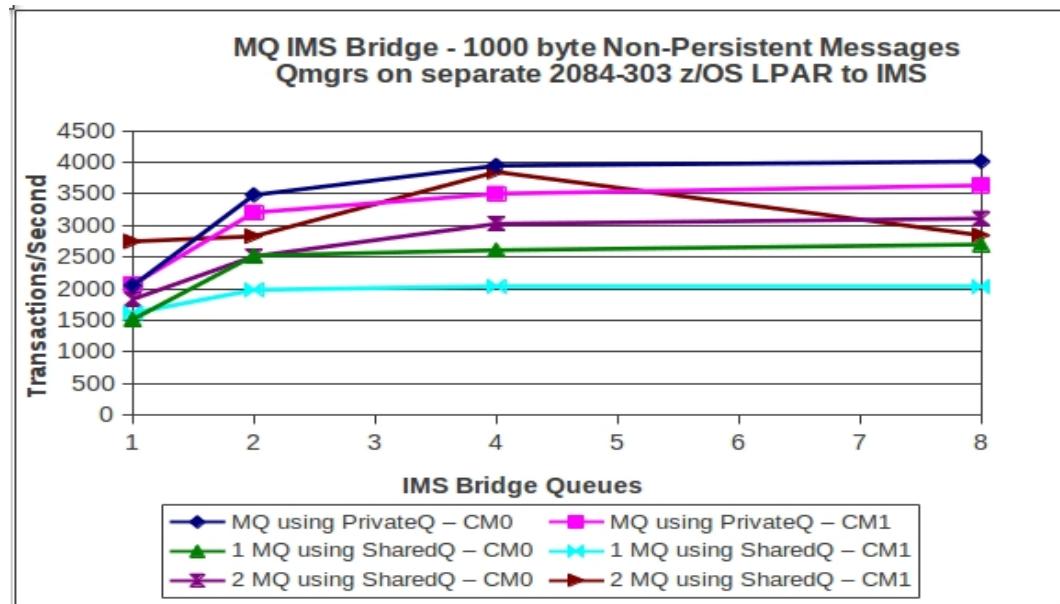


NOTE: When comparing the data from this chart for “CM1 workload on 1 of 3” with the “CM1 – 1000 bytes” data from the “Non-Persistent Message Throughput – Shared Queue” chart, there is a significant increase in through-put. There are several reasons for this:

1. The workload is being run on an LPAR with 5 processors rather than 3
2. The “idle” queue managers on LPARs 2 and 3 both have shared IMS Bridge queues defined and as a result are active in processing messages put by the applications to the IMS Bridge queues and receiving the reply messages sent by IMS.

IMS Bridge Non-Persistent Message Throughput – Remote Queue Manager

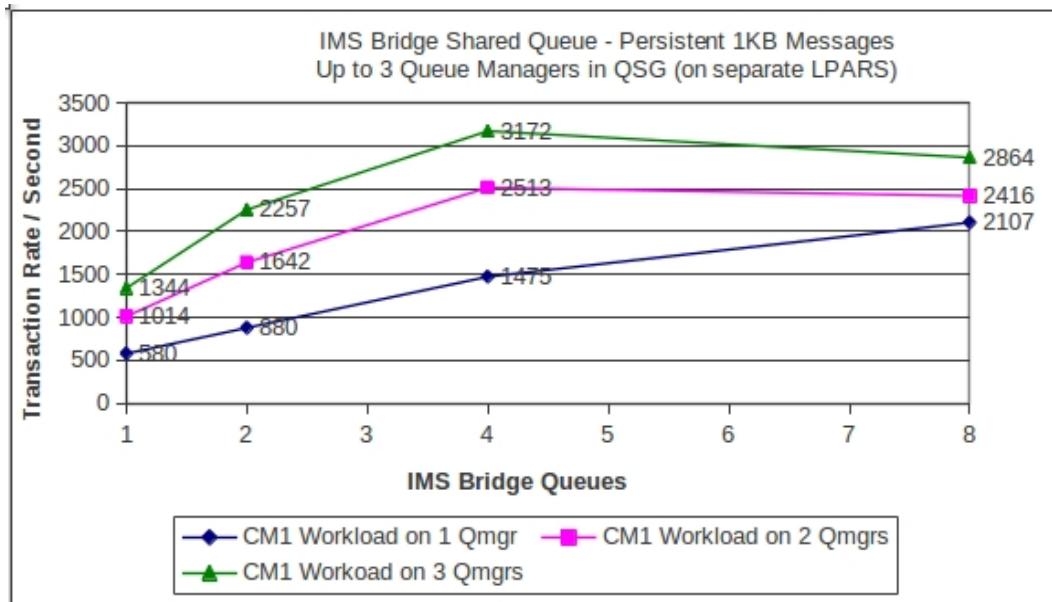
The following chart shows the throughput achieved when there are no queue managers on the same LPAR as the IMS subsystem. This ensures that the OTMA connections are across z/OS's.



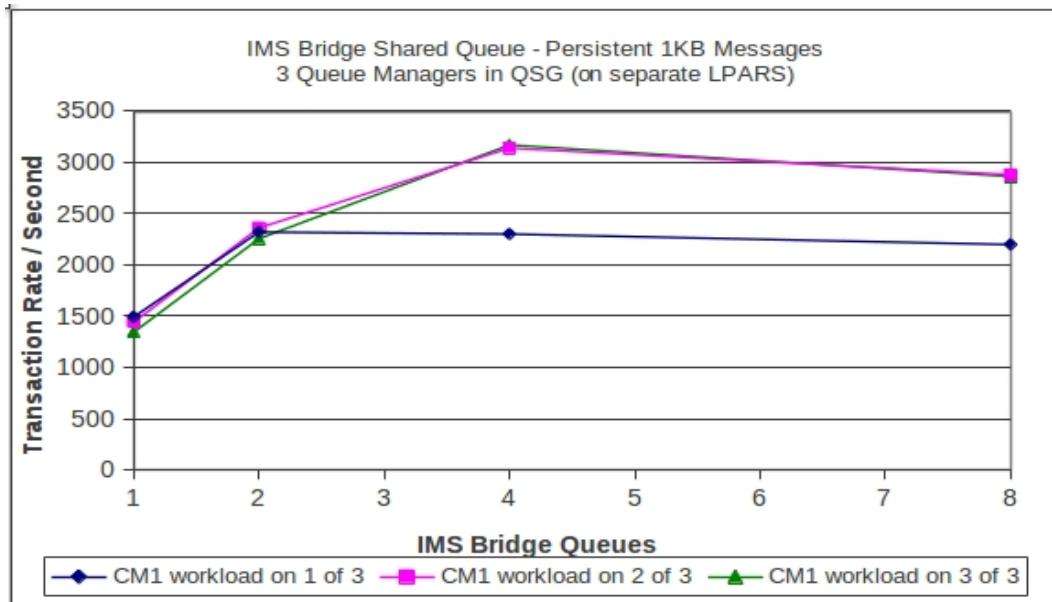
In all of these measurements, there are 16 batch requester tasks, whether there are 1 or 2 queue managers active, or example if there are 2 active queue managers, there are 8 batch requesters connected to each queue manager.

Shared Queue – Persistent Messages

The following chart shows the throughput achieved when the number of queue managers active are all running a workload using 16 batch requesters to drive a varying number of IMS Bridge queues. When there is 1 queue manager active, it is local to the IMS region.

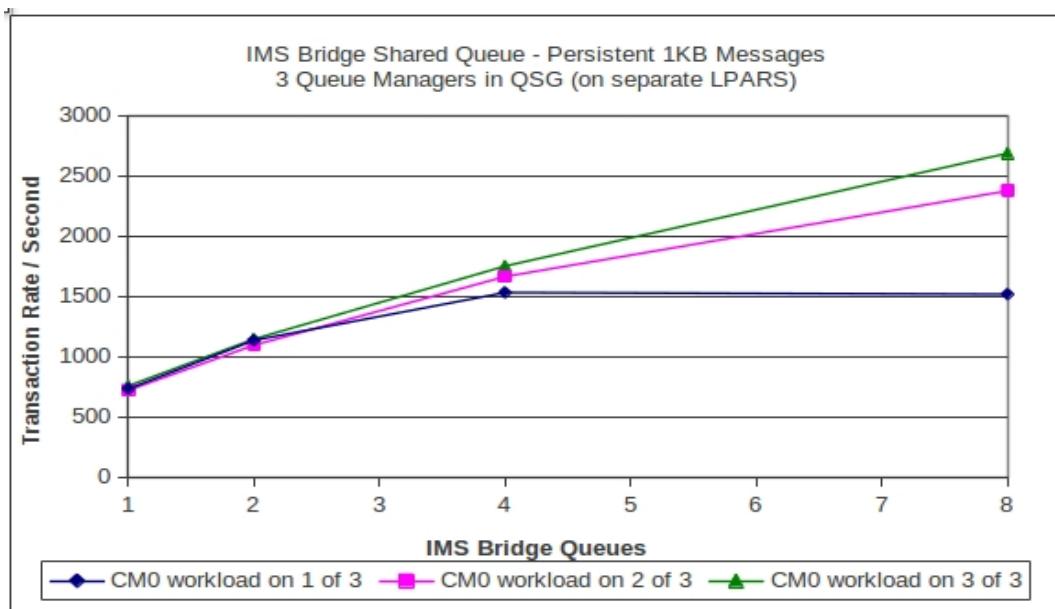


In the following chart, all 3 queue managers are running on separate LPARs but the workload will be run on only 1, 2 or 3 of those queue managers.



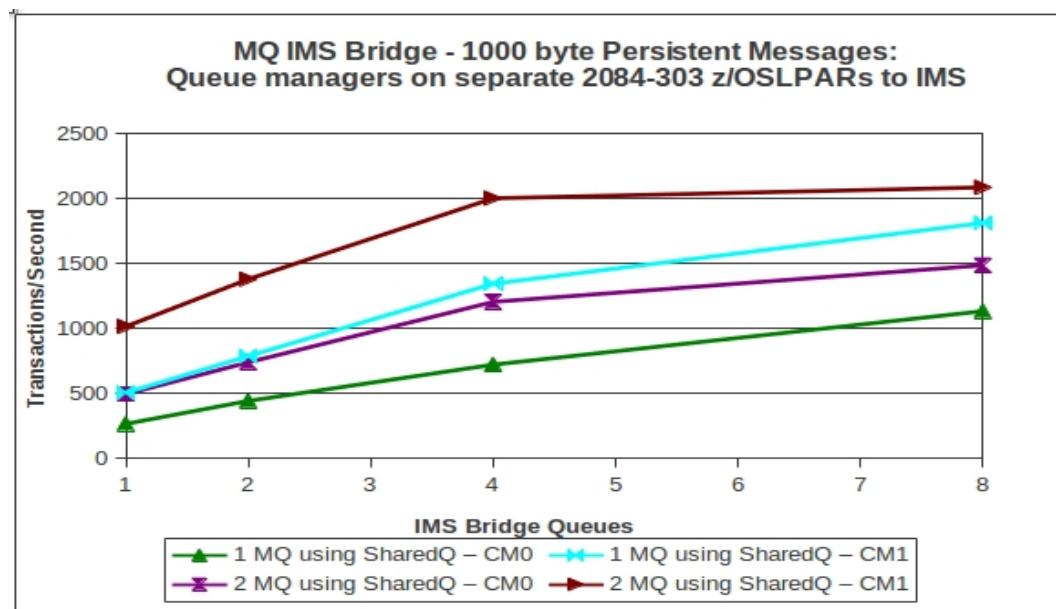
When workload is run on any particular LPAR, there will be 16 batch requester tasks, i.e. when the workload runs on 2 LPARs, there will be a total of 32 batch requester tasks.

The following chart shows the same workload configuration as previously but varies the commit mode to CM0 (Commit-Then-Send)



IMS Bridge Persistent Message Throughput – Remote Queue Manager

The following chart shows the throughput achieved when there are no queue managers on the same LPAR as the IMS subsystem – This ensures that the OTMA connections are across z/OS's.



NOTE: In all of these measurements, there are 16 batch requester tasks, whether there are 1 or 2 queue managers active – if there are 2 active queue managers, there are 8 batch requesters connected to each queue manager.

Chapter 10

Hardware Considerations

CPU cost calculations on other System z hardware

CPU costs can be translated from a measured system to the target system on a different zSeries machine by using Large Systems Performance Reference (LSPR) tables. These are available at: [System z LSPR ITR ratios for IBM processors](#).

The LSPR workload is now calculated on a workload's relative nest intensity. For general IBM MQ workload, it is recommended to use the AVERAGE relative nest intensity value as this is similar to the previous mixed workload levels and is expected to represent the majority of production workloads.

This example shows how to estimate the CPU cost for a zSeries 2097-703 where the measurement results are for a 2094-704:

- The LSPR gives the 2094-704 an average relative nest intensity (RNI) of 3.79
- As the 2094-704 is a 4-way processor, the single engine RNI is $3.79 / 4 = 0.9475$
- The “average” RNI of the 2097-703 used for the measurement is 4.41.
 - The 2097-703 is a 3-way processor.
 - Its single engine ITR is $4.41 / 3 = 1.47$
- The $2094-704 / 2097-703$ single engine ratio is $0.9475 / 1.47 = 0.64$ approximately
 - This means that a single engine of a 2097-703 is nearly 50% more powerful than a single engine of a 2094-704.
- Take a CPU cost of interest from this report, e.g. x CPU microseconds (2094-704) per message, then the equivalent on a 2097-703 will be $x * 0.644$ CPU microseconds per message
- To calculate CPU busy, calculate using the number of processors multiplied either by 1,000 (milliseconds) or 1,000,000 (microseconds) to find the available CPU time per elapsed second.

Example: A 2064-1C5 has 5 processors so has 5,000 milliseconds CPU time available for every elapsed second. So, for a CPU cost of interest from the report of 640 milliseconds on a 2064-1C5, the CPU busy would be: $640 / (5*1000) * 100$ (to calculate as a percentage) = 12.8%

Caveat

Such CPU cost calculations are useful for estimating purposes. However, extrapolation of throughput potential from one system to another is much more risky because limitations other than CPU power may easily become significant. For instance:

- Inadequate BUFFERPOOL size could mean that page set I/O becomes the limiting factor.
- For persistent messages IBM MQ log data rate is often the limiting factor.
- There may be other limitations beyond the scope of IBM MQ whatever the message persistence used. For instance,
 - Network bandwidth when transmitting messages or using IBM MQ thin clients.
 - You also need to factor in all business logic costs and constraints as there are none in our workloads.

Example: LSPR compared to actual results

An initial set of measurements were run by the IBM MQ Performance group comparing MQ workload on a zEnterprise 196 with workload on a z10-EC64 that has been configured in a similar manner.

The following section provides detail of those measurements.

For the set of measurements completed, the zEnterprise 196 out-performed the expectations that were set based on the z10 numbers and the data obtained from the LSPR charts available from:

[System z LSPR ITR ratios for IBM processors.](#)

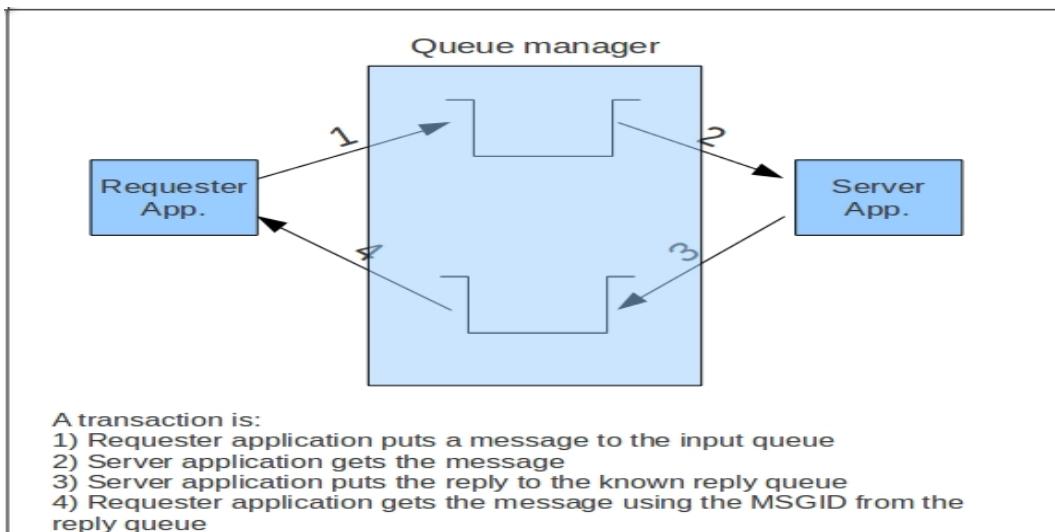
In order to ensure that the tests run on both platforms were directly comparable, only CPU bound tests were run. In conjunction with the relative simplicity of the applications in use, this means that the actual results obtained on the zEnterprise 196 were significantly better than the LSPR may suggest.

Since these tests were CPU bound and the LSPR measurements are based on a mixed type of workload, it is still the recommendation that for production MQ workload estimations, the **average** relative nest intensity (RNI) value is used.

Overview of Environment: Workload

- A set of batch measurements were run against a single WebSphere MQ version 7.0.1 queue manager.
- Only private queues were used.
 - The set of tests incorporated a request/reply model. This took the form shown in the diagram below. Tests were run using non-persistent messages of sizes ranging from 1KB to 100KB.

Request / Reply model



Batch Applications

The batch applications used for the measurements are relatively simple and do not include any business logic.

- The requester application is written in PL/X
- The server application is written in C
- All applications are self-monitoring and determine their costs of interest accordingly.

Hardware systems under test

z10 EC (2097-764)

- LPAR with 3 dedicated CPs – 2097 703 (LSPR)

zEnterprise 196 (2817-780)

- LPAR with 3 dedicated CPs – 2817 703 (LSPR)

LSPR tables

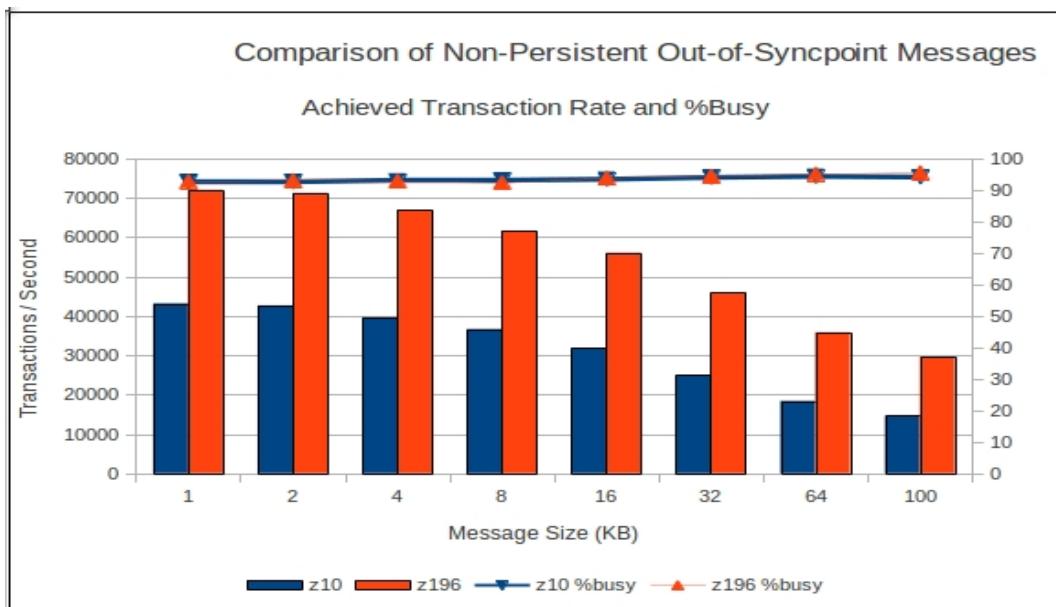
The information below is an extract of the relevant machines' information from the LSPR website for z/OS v1 r11 for “IBM processors running multiple z/OS images”.

Machine	Processor	#CP	PCI	MSU	Low	Average	High
z10 EC	2097-703	3	2468	312	4.7	4.41	3.95
zEnterprise 196	2817-703	3	3311	408	6.13	5.92	5.46

Non-Persistent Out-Of-Syncpoint Messages

This scenario used 5 requester applications that put a non-persistent out-of-syncpoint message to a single queue that is being served by 4 applications that get-next the message and put a reply message to a pre-opened queue. This reply message is then gotten by correlation ID by the original requester task.

The following chart show the achieved transaction rates on the z10 and the z196 machines under test for a range of message sizes. Also shown are the machine utilisation percentages.



Note: As can be seen in the preceding chart, the zEnterprise is able to process transactions at between 65 and 100% faster than the z10. In each case the machine is running at in excess of 90% of capacity.

The following chart shows the average cost per transaction based on the achieved (or external) transaction rate and compares it to the expected costs calculated using the LSPR numbers for the machines under test and the algorithm detailed in the section "[CPU Cost calculations on other System Z hardware](#)".

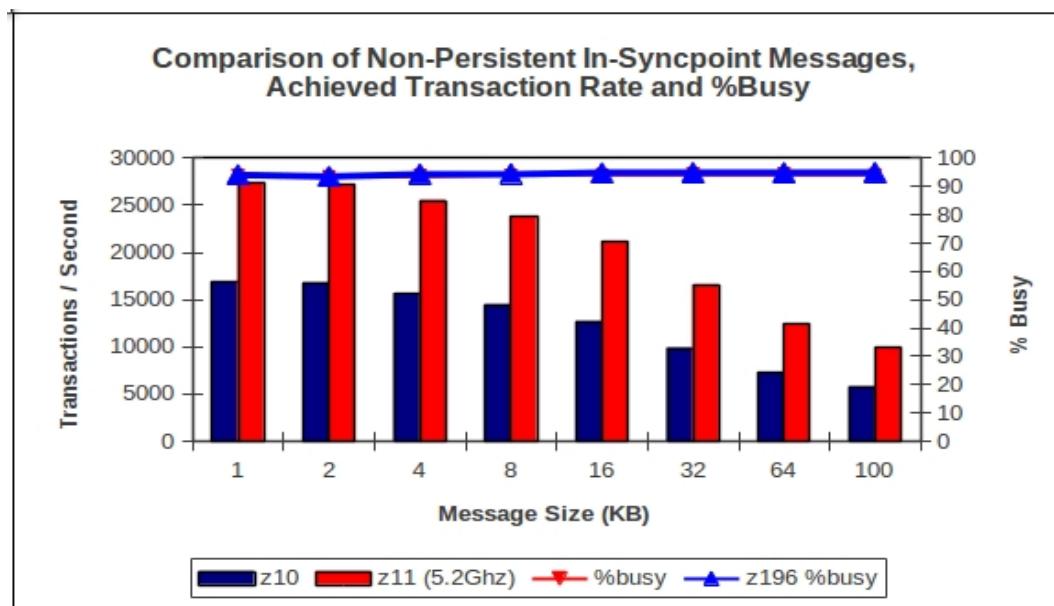
Actual vs Expected costs for Non-Persistent Out-of-Syncpoint Messages



In the above chart, it can be seen that processing a 32KB message on a z10 costs around 110 microseconds, whereas on a z196 a transaction using the same message size costs around 60 microseconds.

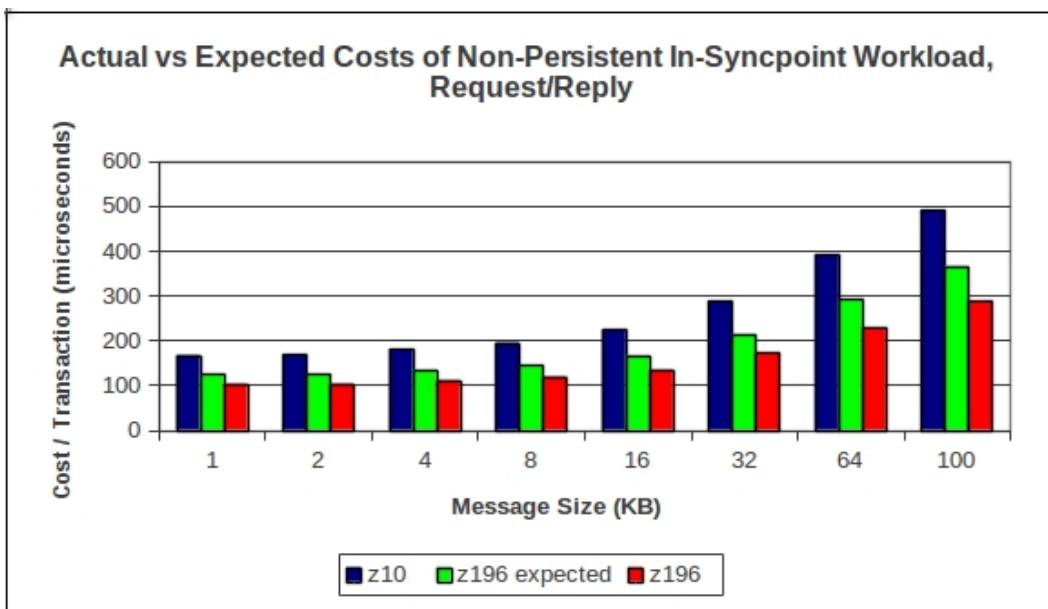
Non-persistent in-syncpoint messages

This scenario used 5 requester applications that put a non-persistent in-syncpoint message to a single queue that is being served by 4 applications that get-next the message and put a reply message to a pre-opened queue. This reply message is then gotten by correlation ID by the original requester task.



Note: In the type of measurement shown in the previous chart, the zEnterprise 196 has processed the transactions between 60% and 70% faster than the equivalent z10. One of the factors in this improvement is the relative simplicity of the measurement and being able to keep as much of the code inside the zEnterprise 196's cache.

The following chart shows the average cost per transaction based on the achieved (or external) transaction rate and compares it to the expected costs calculated using the LSPR numbers for the machines under test and the algorithm detailed in the section "[CPU Cost calculations on other System Z hardware](#)".



Note: In the previous chart, it can be seen that processing a 32KB message on a z10 costs around 290 microseconds, whereas on a zEnterprise 196 a transaction using the same message size costs around 170 microseconds.