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Get More Out of Your IT Infrastructure with IBM z13 I/O Enhancements

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New and expanding workloads are increasingly demanding more from enterprise mainframe systems. These workloads include applications running in the cloud, analytics, mobile device access to business applications, social media, and improvements in security. All these workloads are bombarding the IT systems with requests for information and providing new data to existing business applications. This ever increasing input/output (I/O) activity is stressing the ability of current IT systems to respond.

The IBM® z13™ with many other I/O related improvements is ready to face these challenges.

This IBM Redpaper™ publication discusses the z13 enhancements that enable dramatic improvements for new and expanding workloads, such as cloud, analytics, mobile, social media, and security.

The following topics are covered in this Redpaper publication:

Executive summary

Mainframe workloads and data continue to grow driven by multiple factors. Cloud, analytics, mobile, social, and security (CAMSS) combined with organic growth of traditional mainframe workloads are demanding additional CPU capacity and I/O capabilities in a balanced system. Specifically, cloud requires enhanced virtualization, improved latency, reduced costs and the ability to exchange data efficiently between systems. Analytics is driving the need for improved I/O performance, scale, and availability. Mobile users are generating additional transactions from the systems of engagement to the systems of record and both reside on the mainframe platform. Middleware, such as IBM DB2®, IBM IMS™, IBM CICS®, and IBM WebSphere® MQ leverage the enhanced value of the next generation of IBM mainframes to help support growth. These benefits arise from new architecture features in the mainframe, channel subsystem and I/O channels Fibre Connection (FICON), specifically IBM High Performance FICON® for IBM z Systems™ (zHPF).

Also with z13, 16 Gb link speeds are supported by the IBM FICON Express16S features. The faster link speed provides reduced I/O latency for critical middleware I/O, such as writing the database log. Faster database logging improves DB2 transactional latency. The faster link speed also allows for the shrinking of the batch window, by reducing the elapsed time for I/O bound batch jobs. Because the faster link speed is more sensitive to the quality of the cabling infrastructure, new industry-leading standards are introduced to provide enhanced error correction on optical connections to ensure the smooth transition to 16 Gb Fibre Channel technology. Additionally, the IBM DS8870 support of new T11 standards simplifies diagnosing faulty links from a central management point without the need to manually deploy technicians with light meters to find poor connections and faulty optics.

With z13, infrastructure costs are reduced by allowing FICON channels and Metro Mirror (synchronous disk replication through Peer-to-Peer Remote Copy (PPRC)) I/O traffic to share the same inter-switch links (ISLs) in the storage area network (SAN). This new mainframe feature is called FICON Dynamic Routing (FIDR). With FIDR, SAN fabrics executing FICON can run with SAN dynamic routing policies enabled for both FICON and Fibre Channel Protocol (FCP), thus allowing the same ISLs to be shared. The FIDR feature enables the consolidation of FICON (for example, DASD and tape) and FCP (Metro Mirror, Linux, and VSE) traffic onto a shared pool of ISLs with the best possible utilization of the available bandwidth. The best possible use of the ISL bandwidth comes from using dynamic routing policies in the SAN. For Brocade fabrics, Exchange Based Routing (EBR) provides dynamic routing and for CISCO fabrics, Open Exchange ID (OxID) routing is the dynamic routing policy.

The SAN qualities of service (such as fabric priority) helps compliment the sharing of the ISLs by extending the IBM z/OS® Work Load Manager (WLM) to manage I/O priority of the fabric. This approach ensures that higher priority work runs before lower priority work and with resources needed to achieve higher bandwidth when there is contention. The IBM DS8870 helps complete the picture by correctly echoing back the fabric priority on read requests and by propagating the fabric priority of write requests to the PPRC (FCP) traffic generated that can now flow across the same ISLs as the production FICON work. This approach enables a coherent set of management policies across all of the mainframe-related I/O traffic.

Finally, the scale of the I/O configuration is enhanced to provide more headroom for growth. zHPF is enhanced to eliminate the I/O service time penalty for large write operations at distance, which might occur after a HyperSwap event or in a multi-site workload with application systems running in both sites. Additionally, the addressing limits on the FICON channels are extended to encourage consolidating multiple storage subsystems on the same set of channels (switch distributed star topology). An additional subchannel set is also provided to facilitate the I/O configuration needed to exploit IBM DS8870 multi-target Metro

Mirror (PPRC) with IBM HyperSwap®. Multi-target Metro Mirror avoids running with a single point of failure after the primary DASD fails and the system performs a HyperSwap to the secondary DASD. A second HyperSwap configuration remains, allowing the system to be prepared for another HyperSwap to occur in case of a second disk failure.

Enhancing the value of the I/O infrastructure

The growth in CAMSS workloads drive additional requirements on the z Systems platform to ensure it is able to execute transactions with the same service level agreements (SLA) and enterprise class qualities of service that the most demanding of z Systems clients have come to expect. For example, adding new data sources from the cloud for a work flow might increase elapsed times. Mobile access to data on z Systems might add unpredictable increases in the volume of transactions that occur with the resulting contention affecting SLAs. It is critical that middleware such as DB2, WebSphere MQ, and IMS be able to scale to meet these demands. Lowering database transactional latency is critical to mitigate the impact of new data sources and transaction volumes on both the traditional workloads and also the new work driven directly by CAMSS.

The IBM z13 was built from the casters up for CAMSS workloads, and the I/O enhancements reduce transactional latency thus mitigating increases to transaction response times that might be introduced by adding cloud sourced data to the work flows. These performance improvements also improve the scalability of z/OS and middleware (such as DB2) to meet the demands of mobile applications. The increase in the volume of I/O drives the requirement for further improvements to the already industry-leading quality of service (QoS) capabilities of z Systems. These new QoS enhancements affect processing in the following ways:

- Improve the quality of the Fibre Channel links to reduce error rates.
- Extend the z/OS workload manager into the SAN fabric to manage the end-to-end work according to client-specified policy.
- Provide reduced cost for the physical infrastructure with enhanced virtualization to allow sharing more of the enterprise I/O traffic over shared ISLs.
- Provide improved availability with additional flexibility and scale to the I/O configuration.

IBM z13 is the latest generation of the IBM mainframe to deliver substantial value to the I/O infrastructure:

- Fibre Connection (FICON) Dynamic Routing is a new feature that enables exploitation of SAN dynamic routing polices in the fabric to lower cost and improve performance for supporting I/O devices.
- Mainframe SAN Fabric Priority, with exploiting storage products, extends the z/OS Work Load Manager (WLM) to the SAN infrastructure providing improved resilience and autonomic capabilities while enhancing the value of FICON Dynamic Routing.
- FICON Express16S with the DS8870 can provide substantially improved DB2 transactional latency and up to 32% reduction in elapsed time for I/O bound batch jobs.
- Forward Error Correction (FEC) with supporting storage capabilities to the Fibre Channel link protocol can operate at higher speeds, over longer distances, with reduced power and higher throughput, while retaining the same reliability and robustness that FICON has traditionally been known for.

- zHPF Extended Distance II feature can reduce the impact of distance on I/O response times by 50% for large data writes, providing significant response time improvements for multi-site IBM Parallel Sysplex® environments.
- Scales to six logical channel subsystems (LCSS) allows for up to 85 client usable LPARs.
- All z13 FICON features (FICON Express8, FICON Express8S, and FICON Express16S) can support up to 32K devices allowing further consolidation of more devices onto a set of channels.
- A fourth subchannel set for each logical channel subsystem (LCSS) is provided to eliminate single points of failure for storage after a disk failure by facilitating the exploitation of IBM DS8870 multi-target Metro Mirror storage replication with IBM Geographically Dispersed Parallel Sysplex™ (IBM GDPS®) and IBM Tivoli Storage Productivity Center for Replication HyperSwap.

FICON Express16S

IBM z13 supports the new FICON Express16S channel for improved I/O rates and bandwidth. FICON Express16S has a slight improvement in terms of I/O rates over the FICON Express8S channel, shown in Figure 1.

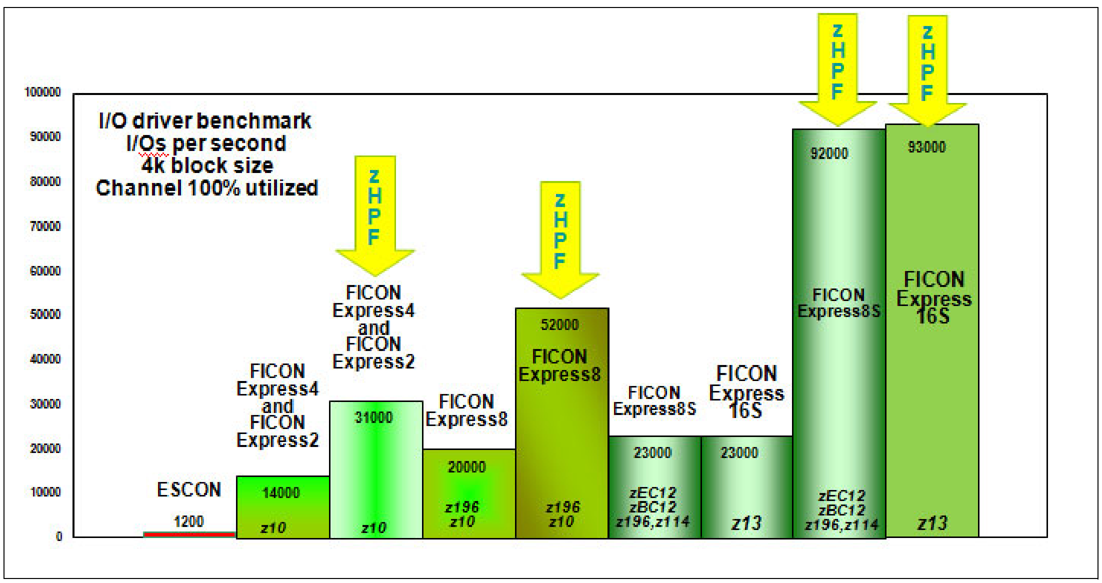


Figure 1 FICON I/O rates: The history of z Systems channel I/O rates. FICON Express16S is able to achieve 93,000 I/O operations per second

Figure 2 shows FICON bandwidth. FICON Express16S provides significant increase in I/O bandwidth and a corresponding improvement in I/O latency for multi-stream large block transfers.

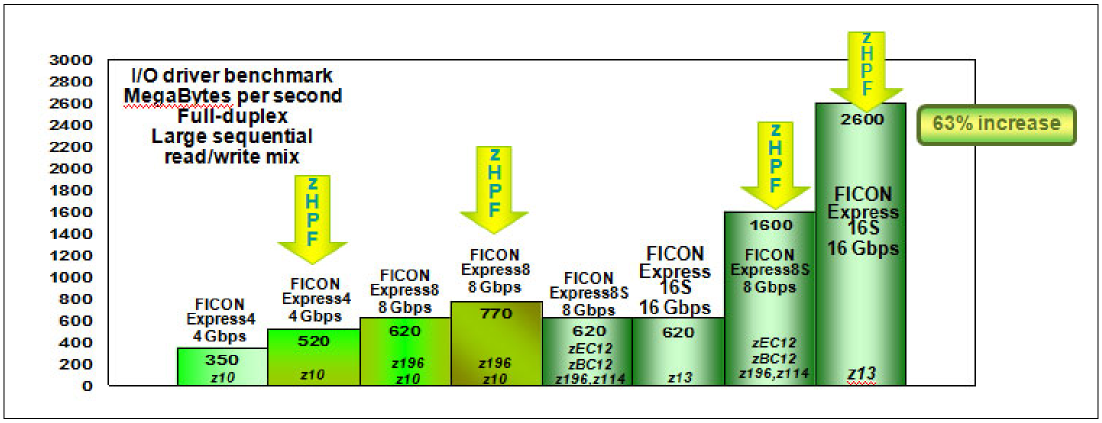


Figure 2 FICON bandwidth: The history of z Systems channel bandwidth. FICON Express16S is able to achieve 2600 MBps bidirectional throughput on 16 gigabit per second (Gbps) Fibre Channel links

Figure 1 on page 4 and Figure 2 show the recent history of the z Systems FICON Express channels and their growing capabilities in terms of increasing I/O rates and link bandwidth. It is important to note two facts from these figures. First, the growth in I/O rates is mostly from zHPF. Second, the growth in link bandwidth also comes mostly with zHPF exploitation. Both of these trends will continue into the future.

Figure 3 shows the I/O latency characteristics of a single 4K I/O request on both the z13 and zEC12 machines using 8 and 16 Gbps link technologies. The FICON Express16S channel with the DS8870 16 Gbps host bus adapter provides the best I/O latency result, up to 21% better than the zEC12.

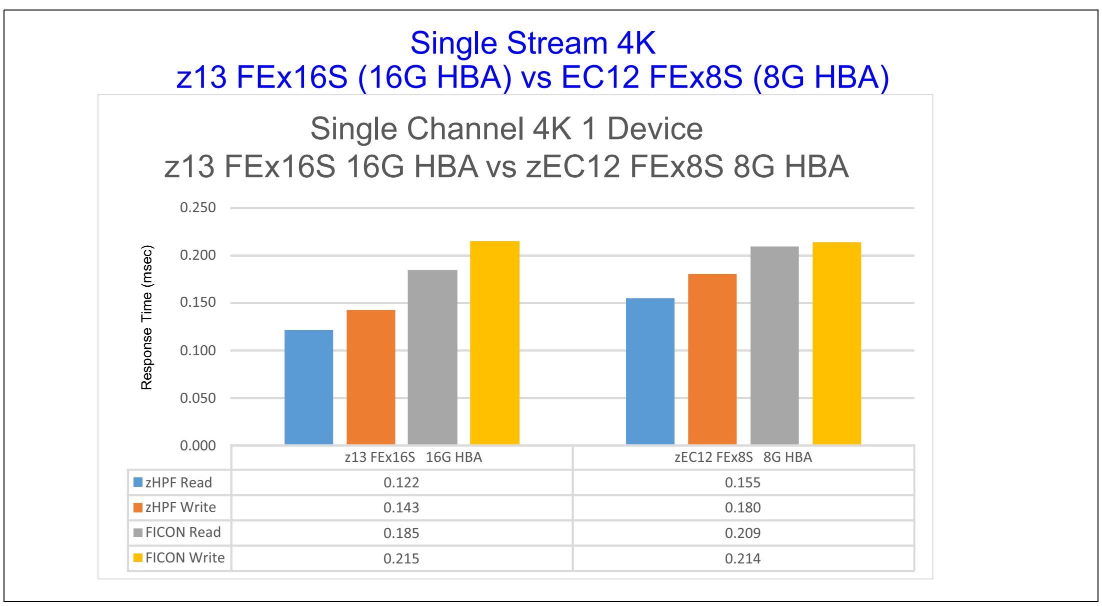


Figure 3 Single stream I/O latency of the z13 with FICON Express16S to a 16 Gb DS8870 versus zEC12 with FICON Express8S to 8 Gb DS8870

The FICON Express16S channel attached to a DS8870 with a 16 Gbps host bus adapter provides the best I/O latency results, as in this example:

- zHPF Read z13 with FICON Express16S Response Time is 21% lower (better) than IBM zEnterprise® EC12 (zEC12) with FICON Express8S (33 microseconds (μsecs))
- zHPF Write z13 with FICON Express16S Response Time is 21% lower (better) than zEC12 with FICON Express8S (37 μsecs)
- FICON Read z13 with FICON Express16S Response Time is 11% lower (better) than zEC12 with FICON Express8S (24 μsecs)
- FICON Write z13 with FICON Express16S Response Time is equivalent to zEC12 with FICON Express8S

The primary value of moving to faster link technologies is in the reduction of I/O latency for "large" read/write operations. For 8 Gb Fibre Channel (FC) link speeds, 5.1 microseconds is required to transport every 4 KB block. For 16 Gb FC link speeds, 2.5 microseconds is required for every 4 KB block. I/O operations that transfer much more data amortizes the overhead of starting the I/O across a very large data transfer leads to a much more substantial improvement. For example, a 128 KB write operation can theoretically have the elapsed time reduced by up to 83.2 microseconds (32 blocks at 2.6 μsec/block). The actual latency improvements depend heavily on the HBA implementation and the channel's ability to move data from the host memory to the HBA.

The time for DB2 to write to the log can be quite a substantial part of the DB2 transaction. A reduction in log write latency improves DB2 transactional latency. As described in the previous paragraph, a 128 KB log write using FICON Express16S for DB2 can result in a measurable I/O service time improvement. For a well-tuned SAP banking workload, 60% of the transactional latency is spent waiting for synchronous I/O. This synchronous I/O is devoted to the write operation to the DB2 log. A reduction to 60% of the latency can yield significant improvements to the DB2 transactional latency.

Figure 4 and Figure 5 on page 7 show the I/O latency times on z13 versus zEC12 when running 256 KB reads and writes using the various link technologies available. In the measurement, four I/O streams were active, half were reads and half were writes. The z13 with FICON Express16S and 16 Gbps DS8870 technology achieved the best possible I/O response times, 32% better than with the zEC12 using 8 Gbps technology.

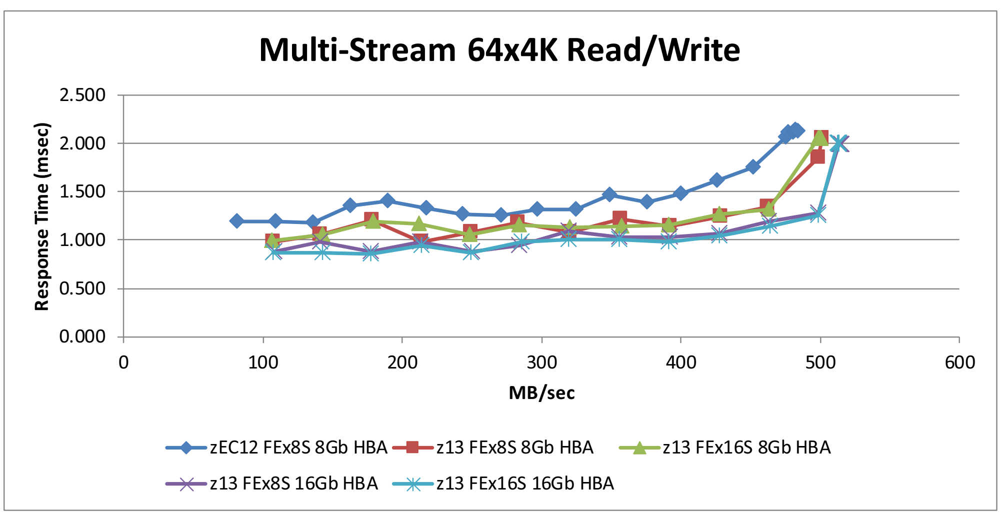
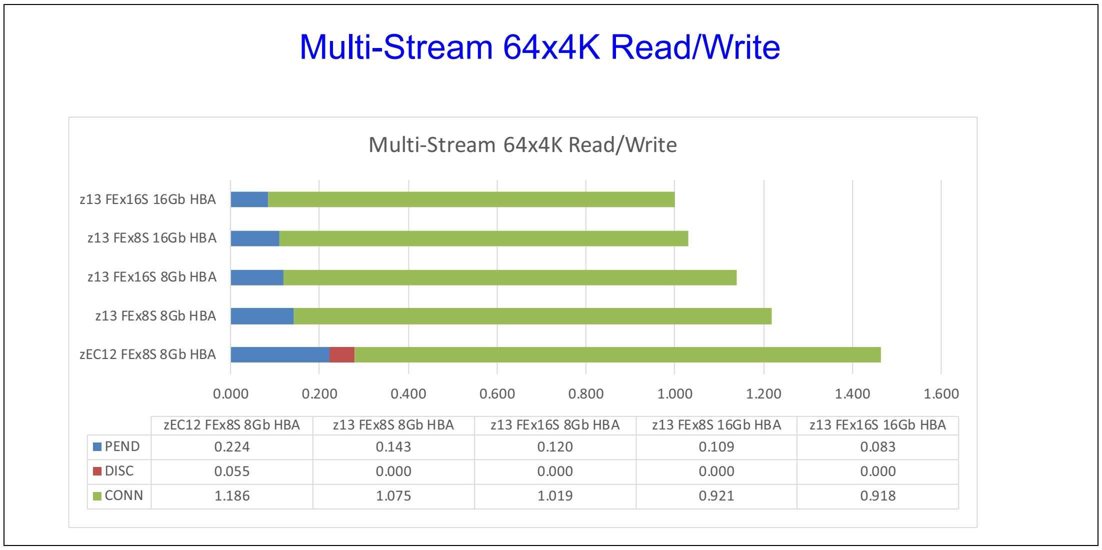


Figure 4 I/O Response times for multiple streams of 256K, 50/50 mix of reads and writes

Figure 5 on page 7 shows relative I/O latency of z13 versus zEC12 with possible combinations of FICON channel and DS8870 link speeds. The FICON Express16S channel running at 16 Gbps to a DS8870 with 16 Gb links provides the best performance for a mixture of reads and writes at 256 KB.



	zEC12 FEx8S 8Gb HBA	z13 FEx8S 8Gb HBA	z13 FEx16S 8Gb HBA	z13 FEx8S 16Gb HBA	z13 FEx16S 16Gb HBA
PEND	0.224	0.143	0.120	0.109	0.083
DISC	0.055	0.000	0.000	0.000	0.000
CONN	1.186	1.075	1.019	0.921	0.918

Figure 5 Relative I/O latency of z13 versus zEC12 with possible combinations of FICON channel and DS8870 link speeds

Relative I/O latency is improved with the z13, as in this example:

- Below 350 MBps z13 FICON Express8S 8Gb HBA response time is 17% lower (better) than zEC12 FICON Express8S 8Gb HBA
- Below 350 MBps z13 FICON Express16S 8Gb HBA response time is 22% lower (better) than zEC12 FICON Express8S 8Gb HBA
- Below 350 MBps z13 FICON Express8S 16Gb HBA response time is 30% lower (better) than zEC12 FICON Express8S 8Gb HBA
- Below 350 MBps z13 FICON Express16S 16Gb HBA response time is 32% lower (better) than zEC12 FICON Express8S 8Gb HBA

Enhancements for FICON Express16S features

Faster Fibre Channel link speeds are more sensitive to the quality of the optical cabling infrastructure. As clients have transitioned from the initial 1 Gbps Fibre Channel link speeds to 2, 4, and 8 Gbps link speeds, the IBM field service team observed more frequent client complaints about increased I/O errors (interface control checks (IFCC)) and the difficulty in detecting the problems before production work is up and running. The quality of the links can degrade as a result of bending or twisting of the fiber cables or because the dust covers are inadvertently left off optical connections while upgrading equipment. In many cases, clients have been carefully managing the cables and connections, but the faster links are ever more sensitive and errors can emerge that do not occur at lower speeds. IBM z Systems are bringing a new Enterprise Class of quality to the FICON Express16S channel to help smooth the transition to faster link speeds.

Specifically, these new capabilities are being offered:

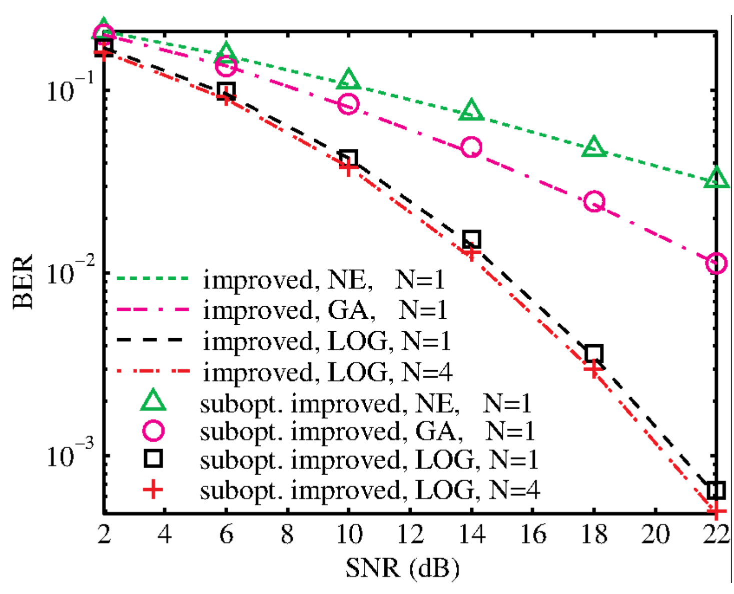
- z Systems tooling helps clients test the link connectivity for new equipment (see “New I/O tooling for testing the I/O configuration” on page 9).
- Industry leading standards to enable Forward Error Correction code technology to automatically improve the quality of the FC links, end-to-end from the channel through the FICON directors to the storage control units.
- Additional industry standards to help identify faulty optical connections from a central point of control, without having to manually deploy people and equipment to find the source of the problem.

Forward Error Correction codes

With the FICON Express16S generation of features, IBM added Forward Error Correction (FEC) capabilities to the Fibre Channel link protocol, using the most advanced FEC coding in the industry. FEC allows FICON channels to operate at higher speeds, over longer distances, with reduced power and higher throughput, while retaining the same reliability and robustness that FICON has traditionally been known for.

FEC is a technique used for controlling errors in data transmission over unreliable or noisy communication channels. The technique has the sender encode messages in a redundant way by using an error-correcting code (ECC). The redundancy allows the receiver to detect a limited number of errors that might occur anywhere in the message and often corrects these errors without retransmission. FEC gives the receiver the ability to correct errors without needing a reverse channel to request retransmission of data, but at the cost of a fixed, higher forward channel bandwidth. Standards have been defined for FEC for data transmission over copper links. IBM, working with IBM Business Partners, delivered an extension to the Fibre Channel standards to enable FEC across optical links.

Figure 6 shows that FEC codes can double the signal loss budget for fiber optic links. FEC improves the bit error rate to the same amount as though the signal were 2.5 dB stronger, relative to the fixed amount of receiver noise.



FEC improves the bit error rate to the same amount *as if* the signal were 2.5 dB stronger, relative to the fixed amount of receiver noise.

Figure 6 Forward Error Correction codes effectively doubles the signal loss budget for fiber optic links

Figure 6 shows that the error rate for an optical transmission is directly related to the signal strength. The FEC standard used by 16 Gbps Fibre Channel HBAs provide the ability to correct up to 11 bit errors in a 2112 bit block. This improvement provides the same relative improvement as doubling the optical signal strength.

With FEC enabled, errors that might have started to show up with the new faster link speeds can likely be corrected by the error correction technology in the optical transmit/receive ports. Clients should see fewer I/O errors, thus easing the transition to the new link technologies, reducing the potential impact to any production workloads by I/O errors. For latency reduction, the entire path (end-to-end) needs to run at 16 Gbps link speed. Likewise, each link, the entire path from the channel through the switch ports to the storage subsystem, should be protected by an FEC-capable link to minimize the risk of I/O errors.

Figure 7 shows the new T11.org[1] standards that are introduced to bring FEC to optical SAN fabrics for z Systems. FEC can improve reliability, availability, and serviceability (RAS) to smooth the transition to the new FICON Express16S technology. IBM led the new standards required to enable FEC for optical links.

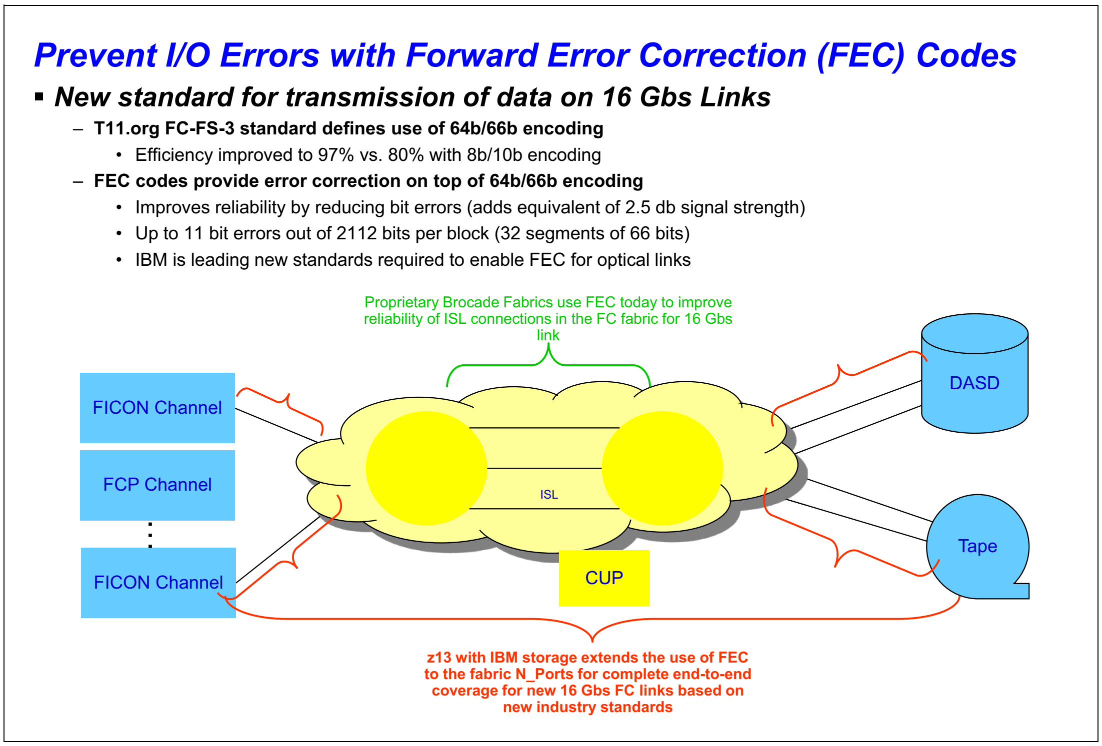


Figure 7 New T11.org standards allow the use of Forward Error Correction codes on optical links for a complete end-to-end resilience enhancement

New I/O tooling for testing the I/O configuration

IBM z Systems provides two new tools for testing the I/O configuration:

- IBM System z® I/O Exerciser (ESAIO)
- IBM z/OS I/O Exerciser

[1] T11 Home Page:
http://www.t11.org/index.html

IBM System z I/O Exerciser (ESAIO)

ESAIO simplifies the chore of exercising the I/O connections in the I/O configuration before starting z/OS and running production work. This tool is intended to help identify possible cabling or definition errors by validating that all the paths defined to each device actually connect to the same physical device. Additionally, a data transfer stress test is performed to help verify the quality of the cabling infrastructure. These tests are especially useful after major infrastructure upgrades (for example, push/pull of a new processor, data center move, and replacing storage devices). By running ESAIO before the operating system IPL and starting a production workload, clients can avoid disruptions to production and ensure that the correct set of devices is put in use.

ESAIO can be installed to run in either a native System LPAR or in an IBM z/VM® environment. The tooling is available at no additional charge from IBM at the following web address (requires a registered user ID and password):

https://www.ibm.com/services/forms/preLogin.do?source=swg-beta-ibmioexzos

IBM z/OS I/O Exerciser

The IBM z/OS I/O Exerciser runs as a started task under z/OS. It can be used to test individual device ranges in a controlled fashion. The IBM z/OS I/O Exerciser is also available at the same web address as the System z I/O Exerciser (ESAIO).

Improved fault isolation

Statement of direction: The IBM DS8870 firmware intends to support the Read Diagnostic Parameters Extended Link Service (RDP ELS), allowing SAN management products to display the diagnostic parameters for its 16 Gbs links. In a future firmware upgrade to the z13, the mainframe links will be displayable by the SAN management products. Additionally, z/OS will be enhanced to display the link information from the z/OS console. This capability will allow clients to diagnose faulty links without having to manually insert light meters to pin point the sources of errors. Finally, z/OS will also provide new SAN diagnostic health checks to identify when the end-to-end paths to a device do not have consistent link speeds and when all the paths to the same control units have inconsistent link speeds.

When the optical signal strength is degraded for some reason or the link is unreliable, bit losses can occur resulting in I/O errors being detected by the host mainframe (IFCC errors). The amount of time for the system to detect the error (with zHPF) might be up to two seconds, and in some cases as long as a missing interrupt handler (MIH) interval (traditional FICON, 30 second default for IBM DASD). The link signal strength might be degraded because of dust or dirt on the optics. Faulty link connections might introduce bit errors because of vibrations in the infrastructure. The abuse of cables (such as, bending, twisting, pulling on optical cables, and leaving off the dust covers) might lead to bit errors.

The challenge for clients is to identify the faulty connection after the hardware upgrades, but before it begins to impact production work. The IBM System z I/O Exerciser described in “IBM System z I/O Exerciser (ESAIO)” on page 10 helps clients test the links. However, when errors are detected, how does the client identify the root cause? In other words, which connection is faulty? The new T11 Read Diagnostic Parameters Extended Link Service (RDP ELS) defines a method for SAN management software in the fabric to retrieve standard counters that describe the optical signal strength (send and receive), error counters, and other critical information for determining the quality of the link. Tools such as the Brocade

Network Advisor (BNA) can be used to display the link information for every architected point in the connection.

Figure 8 shows the intended use of the RDP ELS to programmatically retrieving diagnostic parameters. The diagnostic parameters can assist you in finding the root cause for problematic links in the SAN. After a link error is detected (for example, IFCC: CC3, reset event, link incident report), link data that is returned from RDP is used to differentiate between errors as a result of failures in the optics versus failures as a result of dirty or faulty links. z/OS also provides new operator commands to display the optical signal strength along the route from the channel to the control unit. This enables clients to discover the quality of the signal without having to manually insert light meters along the route. Finally, new z/OS health checks are delivered to detect when the end-to-end link speeds are inconsistent and if all paths to a control unit have inconsistent link speeds. This can simplify diagnosing performance problems.

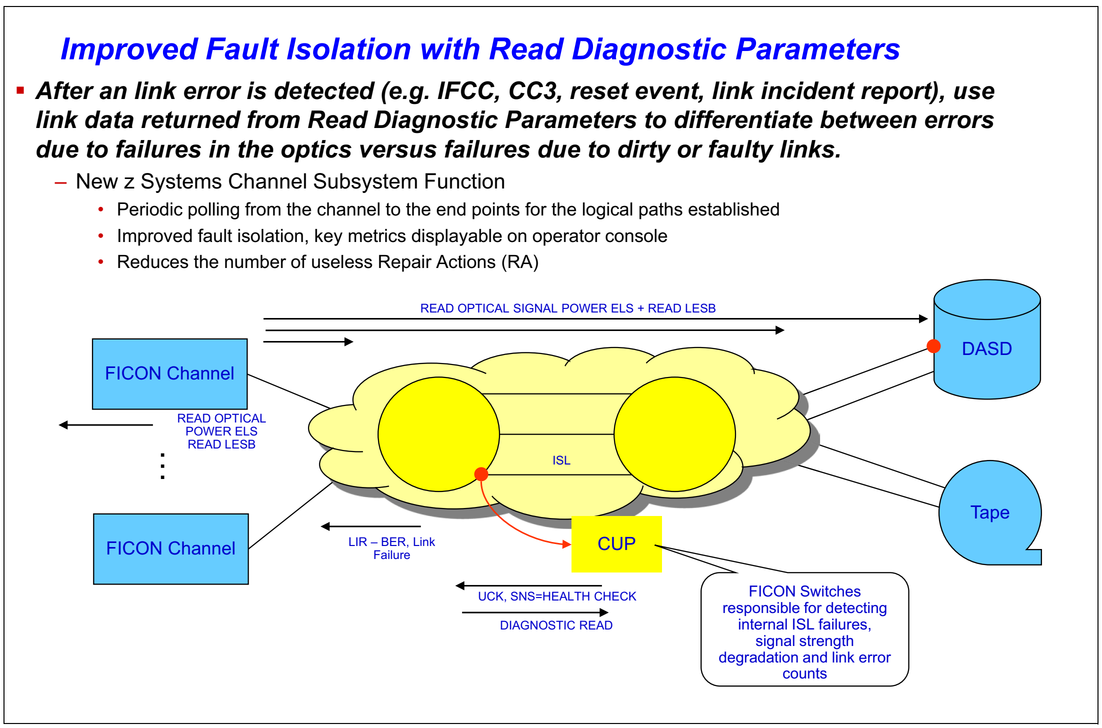


Figure 8 Read Diagnostic Parameters is a new T11.org standard Extended Link Service that provides the instrumentation needed for z Systems to provide enhanced fault isolation

Superior I/O execution at a distance

IBM z Systems have historically been the industry leader in I/O execution at long distance (100 km, 200 km with a request price quotation (RPQ)). The *Information Unit (IU) Pacing* capability built into the traditional FICON protocol was capable of streaming write data to the control unit without the protocol requiring interlocked handshakes between the channel and the control unit. I/O configurations that support the IBM GDPS or IBM Tivoli Storage Productivity Center for Replication HyperSwap capability typically have a local primary control unit and a secondary control unit up to 100 kilometer (km) away. After a permanent error on the primary control unit, z/OS would HyperSwap to the remote control unit. The distance penalty for executing write operations at the remote control unit is offset by the reduction in overhead because PPRC (Metro Mirror) is no longer active. I/O service times for write operations do not elongate. The same is not true for the more recent High Performance

FICON for z Systems (zHPF). While zHPF introduced significant advantages in terms of I/O performance, first failure data capture, and enhanced workload management, z Systems lost the ability to do efficient write operations at long distance. Clients have become exposed to increased I/O service times for write operations. This issue is an inhibitor to the adoption of zHPF, the most critical element of the I/O strategy for the future of z Systems.

Figure 9 shows that with zHPF active, large write I/O service times can double after a HyperSwap to a distant secondary control unit. This experiment was done with DB2 v10 utilities executing 256 KB write operations at 100 km. DB2 v11 does the 512 KB size write operations that might probably cause another substantial increase in I/O service time at long distances.

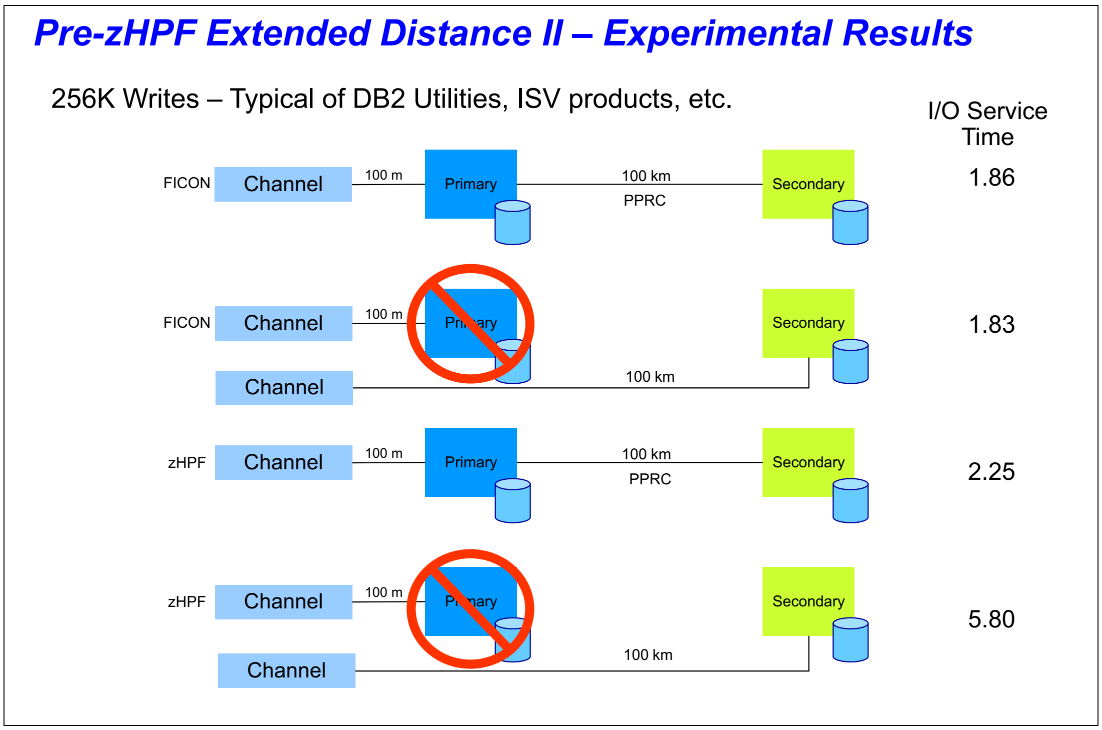


Figure 9 Experiment with zHPF active and large write I/O service to demonstrate I/O service times after a HyperSwap

zHPF is an optional feature that streamlines z Systems I/O execution for a subset of the I/O capabilities. Essentially, zHPF uses the hardware assists built into Fibre Channel host bus adapters (HBAs) for the FCP protocol, to transport z Systems I/O commands while still preserving the z Systems traditional qualities of service such as these:

- In-band I/O measurements
- End-to-end data integrity protection transparent to applications and middleware
- Workload management
- Self-describing components for recognition of single points of failure

The main value of zHPF is I/O performance. Fewer Fibre Channel sequences are needed to execute an I/O operation. I/O latency is reduced and there is less contention at the channel, control unit ports and in the SAN fabric. The zHPF protocol complements traditional FICON, it does not replace it.

Figure 10 shows zHPF Extended Distance II. Prior to a HyperSwap, channels typically execute zHPF protocols to a local primary storage subsystem. Metro Mirror synchronously mirrors the write data to a remote secondary storage subsystem up to 100 km away with no interlocked round trips on the fabric. However, after a failure in the primary control unit, zHPF protocols are used to write the data to the secondary storage subsystem. For the current IBM DS8000® storage implementation, every 66 KB after the initial burst of 64 KB requires an interlocked round trip to write data. At long distance zHPF, I/O performance suffers where traditional FICON performance does not.

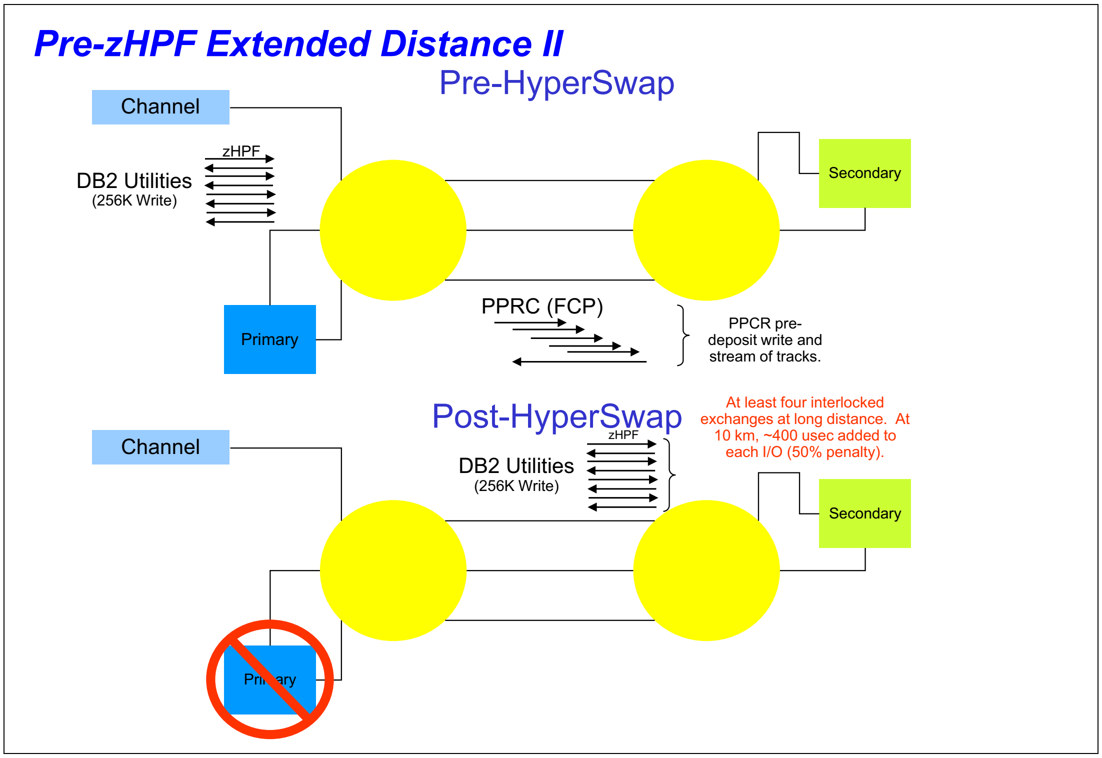


Figure 10 Prior to the z13 zHPF execution of large write operations required multiple interlocked round trips; this would lengthen I/O service times at long distances

Although the zHPF protocol (FCP transport) provides clear advantages and I/O performance, at long distance there are some disadvantages that has discouraged clients from exploiting it. Specifically, execution of large write operations (greater than 64 KB) at distance does not perform as well as traditional FICON. HyperSwap technology provides continuous availability by making a synchronous copy to a secondary control unit and transparently switching when a permanent error occurs, masking the control unit error from the application. Clients typically run to a local primary control unit and might have a secondary control unit up to 100 km away.

The zHPF Extended Distance II capability provided by z13 and the DS8870 enhances the zHPF protocol to allow all write operations to execute in a single round trip to the control unit. This essentially eliminates the *transfer ready* interlocked exchanges that occur for every 64 KB over the FCP transport. It is these interlock round trips at distance that degrade the I/O service time.

Figure 11 on page 14 shows that the new zHPF Extended Distance II protocol provides superior write execution at distance. Most write operations are executed with one round trip through the SAN.

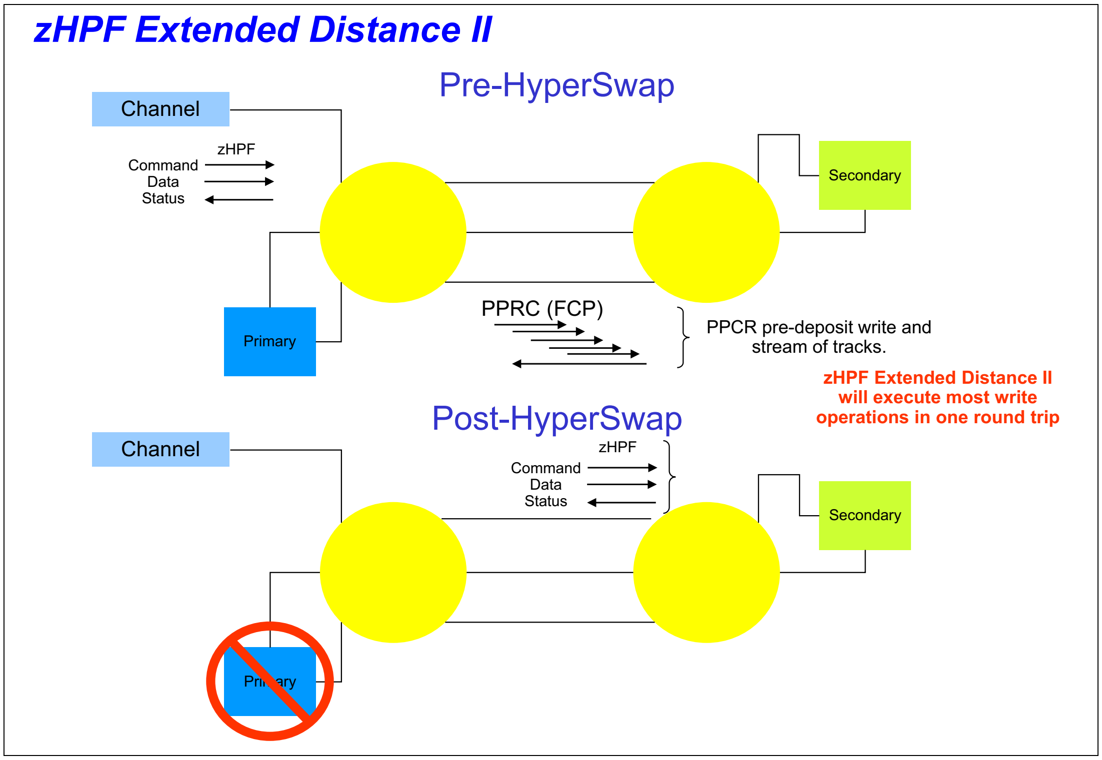


Figure 11 zHPF Extended Distance II provides a protocol change that execute write operations in one interlocked round trip to improve I/O service time at large distances

FICON Dynamic Routing feature

Figure 12 shows the FICON Dynamic Routing (FIDR) a new feature in z13 that allows clients to use dynamic routing policies in the SAN.

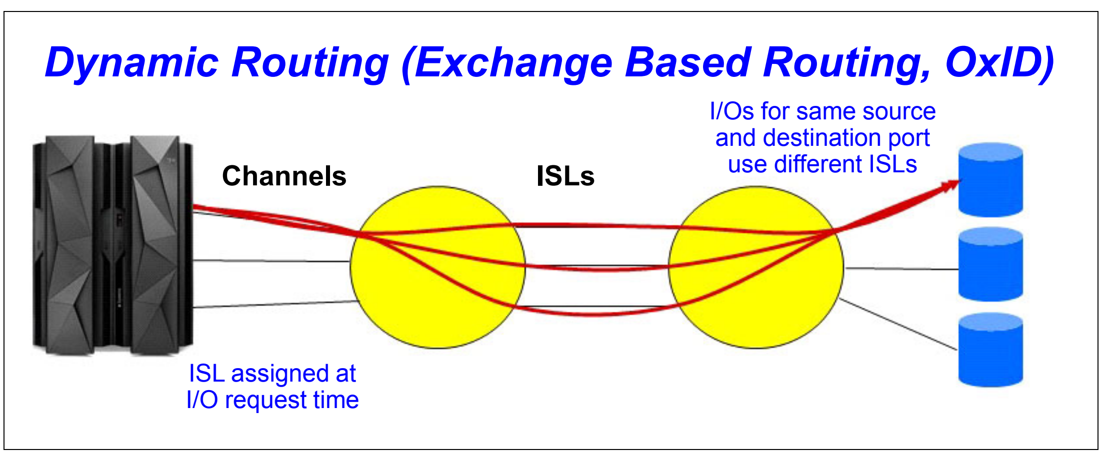


Figure 12 FICON Dynamic Routing is the z System host feature that allows clients to use SAN dynamic routing polices for FICON

With z13, FICON channels are no longer restricted to the use of static SAN routing policies for cascading FICON directors. The z Systems feature that supports dynamic routing in the SAN is called FICON Dynamic Routing (FIDR). It is designed to support both the Brocade static SAN routing policies, including port based routing (PBR) and device based routing (DBR), and also the Brocade dynamic routing policy, exchange based routing (EBR). FIDR also supports both of the Cisco default static routing policy for cascaded SAN switches and Cisco's dynamic routing policy for cascaded SAN switches, Open Exchange ID Routing (OxID). This enhancement is provided to reduce cost, improve performance, simplify management, and position z Systems for future innovations is SAN technology:

- Reduce cost

  The ability for z Systems clients to share their Fibre Channel SANs between FICON traffic and their FCP (PPRC) traffic can reduce costs. Brocade SAN fabrics, ISLs, cannot be shared between virtual switches running with different routing policies. The inability to share ISLs with different routing policies increases costs because it requires additional expense for the following items:

  - Physical hardware including switches, switch ports, and ISL links
  - ISL links that require clients to lease additional dark fibre and bandwidth between sites
  - Personnel and skills to manage the complexity, problem determination, identification of hot spots, instrumentation, and accounting

  Even in a FICON only environment FIDR and SAN dynamic routing policies enable a better balance of the workload over links with predictable and repeatable performance, which can also reduce costs.

- Improve performance

  SAN dynamic routing policies can better exploit all the available ISL bandwidth than static routing policies can. As a result, ISLs can be driven to higher utilization before incurring queuing delays that might result in longer I/O service times.

- Simplify systems management

  Static routing policies can assign different ISL routes from power-on-reset (POR) to POR of the SAN fabric. The routes are assigned without any previous knowledge of the traffic that might occur. As a result, the I/O performance is not predictable or repeatable from POR to POR of the SAN fabric. Additionally, someone must monitor SAN performance, identify hot spots, and perform general problem determination.

Converging FICON and FCP onto shared ISLs

FICON and PPRC (FCP) traffic can be converged onto a single set of shared ISLs in one of two ways. Clients can choose to set a static routing policy such as, DBR and run FICON and PPRC with static routing. Until IBM z13, only static routing polices were supported for FICON. However, the vast majority of the SAN attached distributed systems are using dynamic routing policies.

Alternatively, clients can choose to enable SAN dynamic routing policies with the z13 FICON Dynamic Routing feature and run both FICON and PPRC using EBR (Brocade) or OxID (Cisco). Dynamic routing is intended to allow higher I/O rates and utilization to be driven before I/O queuing delay occurs and utilize all the available ISL bandwidth with predictable and repeatable results.

The advantages and disadvantages of these approaches are discussed in the next sections.

Port-based routing and device-based routing

FICON protocol is designed to use an in-bound and out-bound exchange for communicating between the channel and I/O devices. In-order delivery is required across both Fibre Channel exchanges. Until z13, static routing polices were required to guarantee in-order processing.

Port based routing (PBR) is the original static routing policy provided by Brocade products. PBR has several issues that make it problematic. PBR assigns the ISL routes used statically, based on *first come, first served* at fabric login (FLOGI) time. The actual ISL assigned is selected in *round robin* fashion. This action is done without knowledge of the traffic that will flow. Ports that will never send traffic to the cascaded switch still have ISL routes assigned. This situation sometimes results in some ISLs getting overloaded while other available ISLs are not used at all. The routing can change every time the switch is initialized, resulting in unpredictable, non-repeatable results. Figure 13 shows PBR as a static routing policy that assigns ISL routes as each port logs into the fabric.

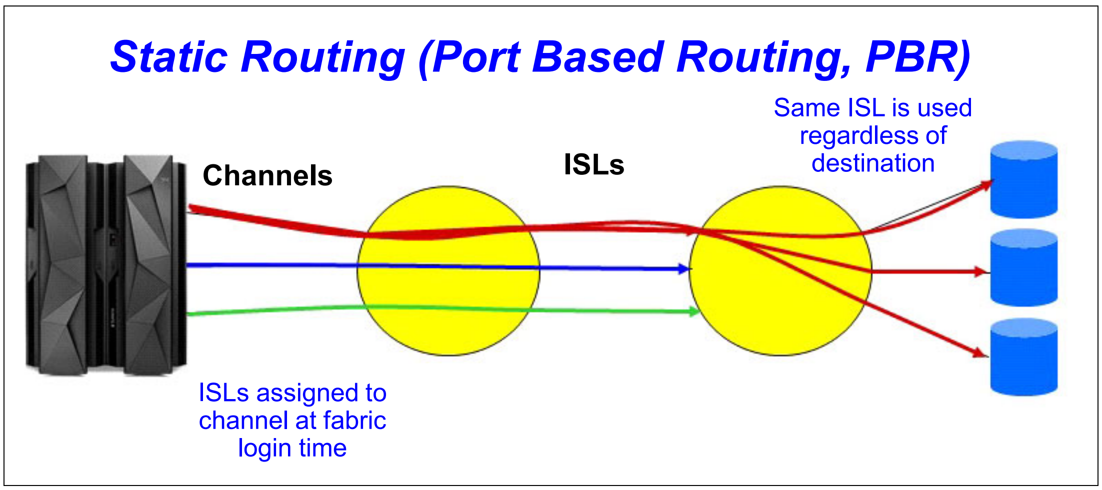


Figure 13 Port based routing is a static routing policy that assigns fixed routes across the SAN at port initialization time

Brocade device based routing (DBR) and the Cisco default routing policy create a set of static routes based on a hash of the source and destination Fibre Channel port addresses. For Brocade FICON Directors, DBR does a much better job of spreading the work over all the available ISLs than PBR.

Figure 14 shows DBR as a static routing policy, however the ISL route is assigned based on a hash of the source and destination port addresses, a method that is much more likely to spread the work across all the available ISLs.

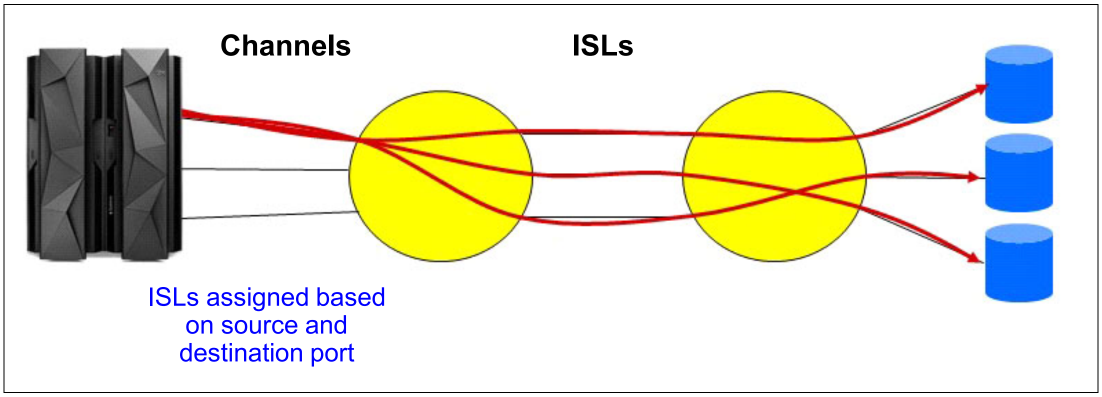


Figure 14 Device based routing is the static routing policy where the ISL route is assigned based on hashing of the source and destination link addresses

Static routing has the advantage of limiting the impact of a slow drain device or a congested ISL to a small set of ports that are mapped to that specific ISL. If congestion occurs in an ISL, the z Systems channel path selection algorithm will detect the congestion through the increasing initial command response (CMR) time in the in-band FICON measurement data. The z Systems channel subsystem begins to steer the I/O traffic away from congested paths and toward better performing paths using the CMR time as a guide. Additional host recovery actions are also available for slow drain devices. For details, see "Dynamic routing policies" on page 17.

The path selection algorithms used by the IBM synchronous replication technology, Metro Mirror (previously called Peer-to-Peer Remote Copy or PPRC), is based on the link bandwidth. The IBM DS8000 keeps track of outstanding PPRC I/O operations on each port. DS8000 path selection chooses the next port to schedule work based on the link with the most available bandwidth. Thus, PPRC traffic should also steer around SAN congestion toward better performing routes.

Static routing polices do not exploit all the ISL bandwidth. Consider a configuration with four PPRC links from the primary control unit to the secondary control unit. These four PPRC ports go to a fabric with eight ISLs. At most, four ISLs will be used. The hashing algorithm might actually map traffic of two or more of the PPRC ports onto the same ISL resulting in fewer than four ISLs actually being used. In many cases, static routing policies will do an adequate job spreading the work across many routes. However, in others, exploitation of the link bandwidth can be suboptimal.

Dynamic routing policies

CISCO and Brocade are the major SAN vendors supporting z Systems and the FICON protocol used for channels to communicate with peripheral devices over Fibre Channel. Both vendors support a dynamic routing policy for the ISL traffic. Dynamic routing polices assign routes to I/O operations dynamically on a per-exchange (I/O operation) basis. This routing technique more effectively spreads the work across all available ISLs. A dynamic routing policy means that there are no fixed routes from the source ports to the destination ports. When everything is running normally ISL resources are utilized equally. This means that links can run at higher utilization without incurring queuing delays. The infrastructure can also better absorb high work load spikes which can occur after temporary disruptions such as, a transient link failure that may result in a reset event and the z/OS recovery process that follows.

Two behaviors can occur in a SAN with dynamic routing enabled that z Systems clients need to be aware of: *dilution* of error threshold counts and the effects of *slow drain devices*.

The first behavior is *dilution* of error threshold counts. Errors can occur in the SAN that cause Fibre Channel frames to get lost. For example, frames can be dropped because of a burst of bit errors that cannot be corrected by the Forward Error Correction codes, for example more than 11 bit errors in a 2112 bit block. For z Systems and FICON an error is then detected by the host operating system. Typically this error will be an “interface control check” or “missing interrupt,” depending on exactly where in the I/O operation the error occurs. These errors are counted by z/OS and tracked to a specific channel and control unit link. With fixed routes, the error count covers the specific ISL that is in the path between the channel and the control unit. With dynamic routing, the intermittent errors caused by a faulty ISL will occur on many channel-to-control unit links, unknown to the operating system or z Systems processor. The error threshold counters can get diluted in that they spread across different operating system counters. It is possible that either the thresholds are not reached in a time period needed to recognize the faulty link or the host thresholds are reached by all control units that cross that ISL resulting in all the channel paths being fenced by the operating system. Therefore, the preference is for you to use the capabilities that the switch vendor provides to set tight error thresholds, internal to the switch, to fence faulty ISLs before the operating system’s recovery processes get invoked.

The second behavior is the *slow drain device*. A slow drain device is a device that does not accept frames at the rate generated by the source. In the presence of slow devices, Fibre Channel networks are likely to lack frame buffers, resulting in switch port credit starvation and potentially choking ISLs. Frames that are considered stuck for a long time might ultimately be dropped by the fabric, resulting in errors being detected. Slow drain devices can occur with static routing policies or with dynamic routing policies in affect.

When a slow drain device event occurs, ISL traffic can become congested. With dynamic routing policies in place, a slow drain device can cause the buffer-to-buffer credit to be consumed from all ISLs that can access the slow device. The congestion spreads and might impact all traffic that needs to cross the shared pool of ISLs. With static routing policies, the congestion is limited to the one ISL that accesses the slow drain device. Possible causes of slow drain devices include an insufficient number of buffer credits configured for links that access devices a long distance away, disparate link speeds between the channel and control unit links, significant differences in the cable lengths, and contention at the control unit HBAs caused when the link traffic exceeds (across all the ports) the capacity of the HBA (which typically can occur when too many Metro Mirror links share the same HBA as FICON links).

The effects of slow drain devices are mitigated by two capabilities of the IBM z13 processor and z/OS:

- The channel path selection algorithms in z Systems steer the I/O work load away from the paths that are congested by the slow drain device, toward the channels in a separate, redundant SAN. Preferred practices for a z Systems I/O configuration require at least two separate and redundant SANs.
- The z13 fabric I/O priority feature with the z/OS Work Load Manager will manage the contention using client-specified goals so that the higher importance work is executed first.

Also worth noting is that for Metro Mirror traffic (FCP protocol), preferred practices call for the client to use dynamic routing policies in the fabric for predictable and repeatable performance, resilience against work load spikes and ISL failures, and also optimal performance. If a slow drain device situation occurs for the fabric with the PPRC traffic, it will impact the synchronous write performance of the FICON traffic because the write operations cannot complete until the data is synchronously copied to the secondary control unit. Therefore, FICON traffic is already subject to the slow drain device scenarios today. Exploiting FIDR does not introduce a new problem to the client and the FICON work load.

New z/OS function is being provided to help clients manage the coexistence of FIDR-capable devices and non-FIDR-capable devices in the enterprise. For example, z Systems, z/OS, SAN vendors, and storage vendors will all support a new SAN health check to detect when non-FIDR-capable devices and non-FIDR-capable processors are attached to switches running with dynamic routing policies enabled. This alerts clients to the possible I/O errors that can occur. Additionally, new configuration definition options are supported by the z Systems Hardware Configuration Definition (HCD) dialog to allow clients to designate which switches and devices are intended to be run with dynamic routing policies enabled. This will help prevent clients from accidentally dynamically adding a non-FIDR capable device to a FICON director running with FIDR enabled.

Autonomic management of the SAN Fabric using I/O priority

IBM z13 provides a new designed means for the host operating system software to specify an I/O priority for the SAN fabric use. This capability allows z/OS to extend the z/OS WLM[2] to manage the SAN fabric, completing the management of the entire end-to-end flow of an I/O operation[3]. The z/OS operating system does this by first querying the range of supported fabric priorities from each SAN switch in the I/O configuration. From this information, z/OS derives a priority range supported across all physical switches. WLM then assigns I/O priorities consistent with client-specified goals for the workloads within the supported range.

With the fabric I/O priority specified by WLM, the write operations will be managed by the fabric. For read operations, when the DS8000 sends the data to the host, the DS8000 will indicate the I/O priority specified by WLM on the original read I/O command, which will enable the fabric to manage the return of the data to the host according to the appropriate priority. This unique capability for IBM storage is required to support the FIDR strategy described in “FICON Dynamic Routing feature” on page 14. As more I/O work shares a pool of ISLs, fabric priority is a critical capability for managing performance toward the client goals. The IBM DS8870 is also enhanced to propagate the fabric priority of the write operations that require replication services, such as IBM Metro Mirror to the PPRC FCP-based, generated I/O activity. This innovation provides a true end-to-end workload management capability for z/OS traffic through the SAN infrastructure.

Under normal operating conditions, clients typically run with enough I/O resource (ISLs) to minimize I/O contention. However, workload spikes can occur that lead to contention. Additionally, hardware failures might occur that reduce the number of switches and ISLs available for execution of the workload. Under these circumstances, fabric priority is especially useful to provide additional resilience and allow z/OS WLM to deliver the I/O capabilities to the most important work first.

While the fabric vendors have had the hardware capability for providing in-band control of qualities of service (QoS), no other system platform besides z Systems and z/OS have been able to take advantage of such capability with a dynamic integrated solution based on client specified polices. Other distributed system platforms typically require clients to establish

[2] Robert Vaupel, *Managing Workloads in z/OS*, IBM Systems Magazine, January 2004: http://www.ibmsystemsmag.com/mainframe/administrator/systemsmanagement/Managing-Workloads-in-z-OS/

[3] Harry M. Yudenfriend, *System z Innovations Automatically Define Configurations for Greater Availability*, IBM Systems Magazine, July 2013: http://www.ibmsystemsmag.com/mainframe/storage/Data-Management/zdac_yudenfriend/

separate fabric zones with fixed priorities assigned for the fabric priority. The z Systems and z/OS provide a comprehensive end-to-end I/O priority management with the z/OS WLM technology, middleware integration into the I/O stack, z Systems architecture, FICON[4] I/O transport, SAN extensions, and cooperating storage such as the IBM DS8870 Storage Subsystem.

Figure 15 shows the z Systems Fabric Priority where the z Systems channels are able to specify the SAN fabric priority to be used in execution of the I/O operation. z Systems storage subsystems exploit by echoing the priority back on read operations and propagating the priority to the copy services traffic that is generated by the write operations.

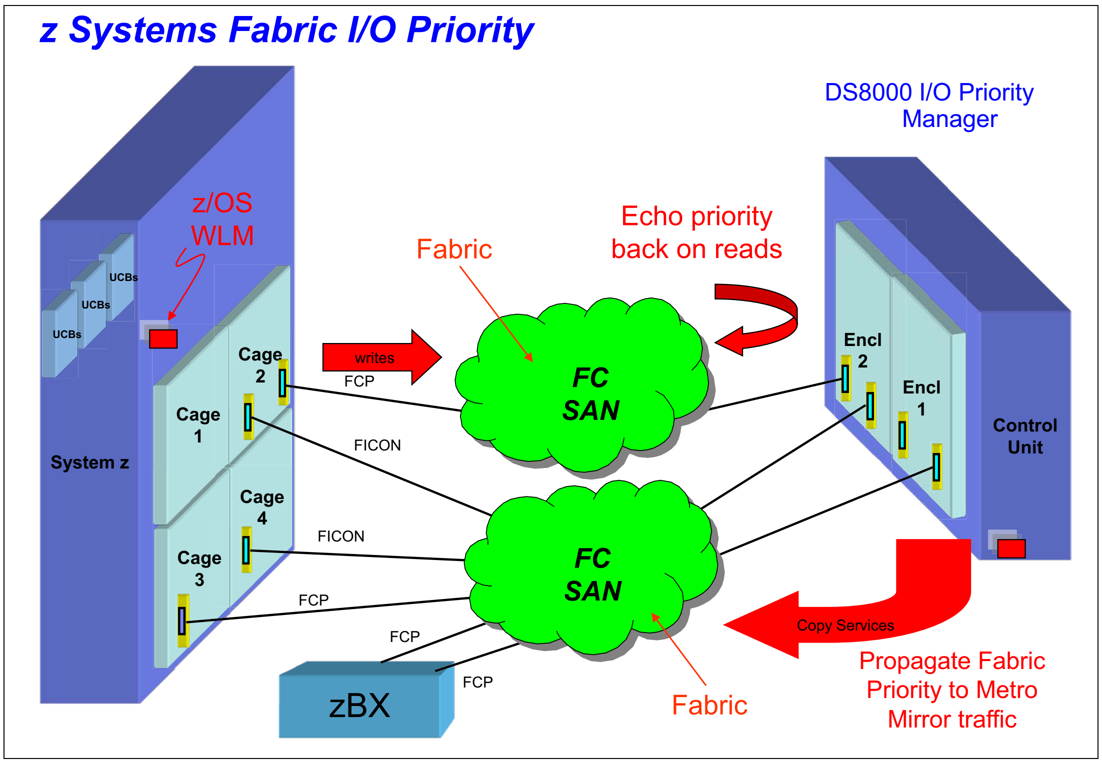


Figure 15 z Systems Fabric Priority extends z/OS WLM goal-based polices into the SAN infrastructure. The IBM DS8870 compliments this feature with unique support to echo the priority back on read requests and to propagate the priority to the Metro Mirror FCP traffic generated by write requests

Eliminating single points of failure with storage

GDPS HyperSwap and Tivoli Storage Productivity Center for Replication Basic HyperSwap provide z/OS client's continuous availability by masking control unit failures. The HyperSwap function is implemented by redirecting I/O from a set of primary devices to a set of secondary devices by switching the subchannel representing the device. Without multi-target PPRC, clients are running an environment with a single point of failure after a HyperSwap occurs. In some geographies, regulatory compliance requires the clients to report to the government when they are running with a single point of failure. Multi-target PPRC with HyperSwap eliminates the single point of failure after the primary disk failure.

4 *FICON Planning and Implementation Guide*, SG24-6497 has more details.

With multi-target PPRC, clients can have a third synchronous copy of the data (one primary and two synchronous secondary copies). Figure 16 shows that the fourth subchannel set facilitates the I/O configuration definition for the second synchronous copy of the data so that it is available to be used by a second HyperSwap and the first HyperSwap occurs. Such a capability eliminates DASD as a single point of failure after the first control unit failure.

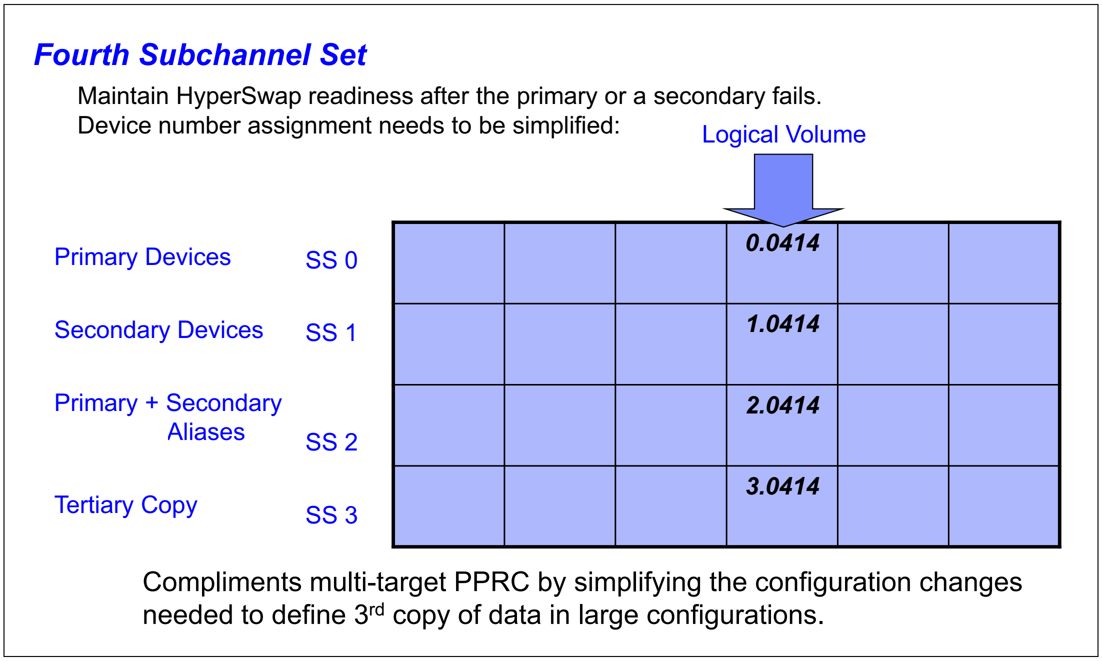


Figure 16 The z13 adds a fourth subchannel set to facilitate the use of DS8870 Multi-Target Metro Mirror and HyperSwap

Scalability

IBM z13 delivers additional scale to allow clients to consolidate LPARs and processors onto fewer and fewer footprints. Up to 85 LPARs are supported for client use across up to six logical channel subsystems.

All the FICON Express channels that are supported by z13 support up to 32K I/O devices per channel, up from 24K per channel on the previous generation. This increase in channel addressing capability offers benefits in many ways. Clients can more easily create disaster recovery configurations with an I/O configuration predefined to handle a wider range of possible workloads. A single channel can be used to address both the primary and secondary storage subsystems when using Metro Mirror and GDPS and Tivoli Storage Productivity Center for Replication HyperSwap for continuous availability. With the more powerful channels and zHPF becoming a ubiquitous feature, clients can choose to have many more devices on the channel to take advantage of the higher I/O rates and channel bandwidth that is now available. Finally, with the switch-distributed star topology of a FICON SAN, more control units can be added to a set of channels to possibly reduce the number of I/O slots needed in the z Systems platform. For clients that have this constraint, this can free up slots for new value-added features such as Flash Express for high availability and zEDC for saving on the cost of storage capacity and link bandwidth.

Conclusion

IBM z13 offers a compelling set of functions to enhance the value of the IBM z Systems family, as follows:

- FICON Dynamic Routing to reduce hardware and people management costs
- Fabric Priority to improve resilience
- FICON Express16S features to enhance database transactional latency and reduce the batch window
- Forward Error Correction codes to make the transition to FICON Express16S go smoothly and improve reliability
- Read Diagnostic Parameters to improve RAS

IBM z13 also has enhanced zHPF protocols to improve I/O execution of write commands by reducing I/O service times at distance. The scale of the I/O configuration is increased to encourage switch distributed star topologies and reduce the total number of FICON channels needed. Finally, the exploitation of multi-target PPRC with HyperSwap technology is encouraged with the addition of a new subchannel set to simplify the I/O configuration definition task.

Table 1 identifies key functions and provides a description of each function and it value.

Table 1 Key functions and their description

Function	Description
FICON Express16S features	Faster links will improve I/O latency. For DB2 Log Writes, 16 Gbps zHPF will improve DB2 log write latency and throughput by up to 32% with multiple I/O streams, resulting in improved DB2 transactional latency. For multi-stream I/O bound batch jobs, clients can expect up to a 32% reduction in elapsed time.
Forward Error Correction codes	The faster link speed technologies are more sensitive to the quality of the cabling infrastructure. IBM is leading a new industry standard to provide FEC for optical connections. This can provide the ability to correct up to 11 bit errors out of a block of 2112 bits, the same benefit that can occur as though the optical signal strength was increased 2x, yielding substantially reduced I/O link errors. This technology allows z System I/O to operate at higher speeds, over longer distances, with reduced power and higher throughput, while retaining the same reliability and robustness that FICON is traditionally known for.
zHPF Extended Distance II	Clients using multi-site configurations can expect up to 50% I/O service time improvement when writing data remotely (remote site recovery). This capability is required especially for GDPS HyperSwap configurations where the secondary DASD subsystem is in another site.
FICON Dynamic Routing	New z System host feature that allows clients to use SAN dynamic routing policies across cascaded FICON Directors. This simplifies configuration and capacity planning, provides persistent and repeatable performance, and is more resilient after hardware failures by allowing the ISLs to be driven to higher utilizations before encountering queuing delays. Configuration planning is simplified and hardware costs are reduced by allowing FICON and FCP (PPRC) to share the same switch infrastructure without creating separate virtual switches and adding ISLs.

Function	Description
Fabric Priority	With SAN Fabric Priority, important work gets done first when SAN hardware failures result in traffic congestion. This is achieved by extending the z/OS WLM policy into the SAN fabric leveraging capabilities of the SAN vendors. z/OS and z Systems are the first platforms to provide an integrated workload management function that exploits this industry feature.
Scale	Scales to six logical channel subsystems (LCSS) allows for up to 85 client usable LPARs, up to four subchannel sets per LCSS for added flexibility. All FICON channels supported on z13 (FICON Express8, FICON Express8S, and FICON Express16S) can support up to 32K devices per channel.
Resilience	A fourth subchannel set for each LCSS is provided to facilitate elimination of single points of failure for storage after a disk failure by facilitating the exploitation of IBM DS8870 multi-target Metro Mirror storage replication with GDPS and Tivoli Storage Productivity Center for Replication HyperSwap.
z13 GA2 SOD Resilience	Integrated instrumentation to allow clients to find potential trouble spots in the SAN without manually inserting light meters around the machine room. This can help reduce false Repair Actions (no defect found, NDF). z/OS can also automatically differentiate between errors that are caused by faulty components versus dirty optical connections. z/OS can also better identify the failing component that introduces the I/O errors into the configuration.

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Thanks to the following people for their contributions to this project:

LindaMay Patterson, Bill White
International Technical Support Organization, Poughkeepsie Center

John Eells, John Flanagan, Dale Riedy, Chris Colonna, Brian Murphy
IBM Systems & Technology Group, z Systems, Poughkeepsie

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This document REDP-5134-00 was created or updated on February 4, 2015.

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