ESS FICON Channel Attachment

Version 3.0

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Preface

This paper describes the new FICON interface attachment for the ESS. The reader is strongly encouraged to read the white paper, "Enterprise Storage Server Fibre Channel Attachment", which is located on the ESS web site at the following location:

http://www.storage.ibm.com/hardsoft/products/ess/support/essfcwp.pdf

It contains a general description of the Fibre Channel architecture and defines many of the terms that are used in this paper.

Also, I would like to thank John Ponder for authoring the entire performance section ("FICON Configuration and Performance Considerations").

Introduction

FICON is a new interface for the ESS. It is used for attaching S/390 control units to S/390 systems, and is based on the industry standard Fibre Channel architecture. In this new interface the ESCON protocols have been mapped to the FC-4 layer, i.e., the Upper Level Protocol (ULP) layer, of the Fibre Channel architecture. This mapping has two main benefits. First, it puts the S/390 interface on the Fibre Channel industry standard base so that it can take advantage of all the functionality that this base provides, along with the high quality and low costs that come with high volume components. Second, it provides a fully compatible interface for the existing S/390 software. Only minor software changes are required in order to exploit the full functionality of FICON.

FICON supports many improvements over ESCON and relieves many ESCON architectural limitations. Just as ESCON did not replace the parallel OEMI S/390 channel interface when it was first introduced in early 1991, FICON will not replace ESCON at its introduction. The two interfaces will both be supported on IBM's S/390 systems and on ESS for many years to come.

IBM introduced FICON late in 1999 on the S/390 G5/G6 servers. A FICON bridge product that converts FICON to ESCON was delivered at the same time and allowed our S/390 customers to transition to FICON channels and still attach to ESCON control units. This FICON bridge product is a special feature on the 9032 Model 5 ESCON Director. FICON is now supported on the new S/390 z900 servers.

IBM will be rolling out native FICON storage products in phases. The first phase will include tape and printer products, closely followed by ESS-FICON in the second phase.

FICON Characteristics

FICON is based on the standard Fibre Channel architecture, and therefore shares the attributes associated with Fibre Channel. This includes the common FC-0, FC-1, and FC-2 architectural layers, the 200 MB/s bidirectional (full duplex) data transfer rate, and the point-to-point distance capability of 10 kilometers. Additional characteristics are listed below:

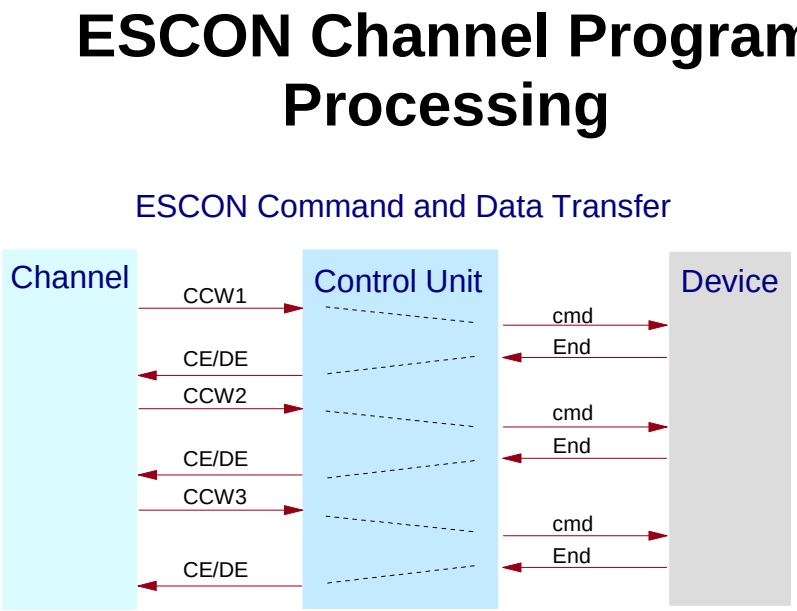
- Attachment is via either the point-to-point topology or the switched topology.
  - In the point-to-point topology a single link is connected from a FICON channel to a port on a FICON control unit.
  - In the switched topology, one link is connected from a FICON channel to a port on a switch, and another link is connected from a port on a FICON control unit to a port on the same switch.
- Attachment requires that the point-to-point protocol be used. (The point-to-point protocol is used when the topology is either point-to-point or switched.) The loop protocol is not supported for FICON.
- FICON protocol uses class 3 service primarily, but switches to class 2 for some initialization and recovery functions.
- FICON will be supported with both long wave and short wave laser adapters.
  - 9 micron single mode fiber will be the commonly supported media for the long wave adapter. However, either 50 or 62.5 micron multimode fiber can be used at reduced distances with the use of a mode conditioning cable at each end.
  - Either 50 or 62.5 micron multimode fiber can be used with the short wave adapter.
- The number of control unit images that can be architecturally addressed at a control unit port has increased from 16 for ESCON to 256 for FICON. ESS initially implements a maximum of 16 FICON control unit images.
- The number of devices that can be architecturally addressed at a control unit port has increased from 4K for ESCON to 64K for FICON. ESS initially implements a maximum of 4096 devices that can be addressed.
- The maximum attachment distance between the channel and the control unit, via the use of distance extender products, without incurring a data rate droop, has been increased from approximately 9 kilometers for ESCON, to 100 kilometers for FICON.
- Channel Command Word (CCW) pipelining, where multiple CCWs are streamed from the channel to the control unit without intermediate status or acknowledgments, has been designed into the FICON protocol.
- Channel program multiplexing, where multiple channel programs - to the same or different control units - can be ongoing on the FICON link at the same time, has been designed into the FICON protocol.

FICON / ESCON Comparison

	FICON	ESCON
Link Rate	212 MB/s	20 MB/s
Effective Data Rate **Architected** **Implemented**	 200 MB/s 60 MB/s	 18 MB/s 10-13 MB/s
Maximum Throughput **G5/G6** **z900**	 3600 IO/s 4800 IO/s	1100 IO/s
Maximum Distance **(No Repeaters)**	10 km 20 km with RPQ	3 km
Maximum Distance Without Data Rate Droop	100 km	9 km
Frame Transfer Buffer	128 KB	2 KB
CU Images / CU Port **Architected** **Implemented**	 256 16	 16 16
UAs / Channel **Architected** **Implemented**	 16M 16K	 1M 1K
UAs / Control Unit **Architected** **Implemented**	 64K 4K	 4K 4K
CU Logical Paths / CU Port	256	64
Logical Paths / LSS	128	128
Command Execution	Nonsynchronous	Synchronous

Sample Channel Program Execution

The following diagram shows a sample CCW chain being executed on an ESCON interface:

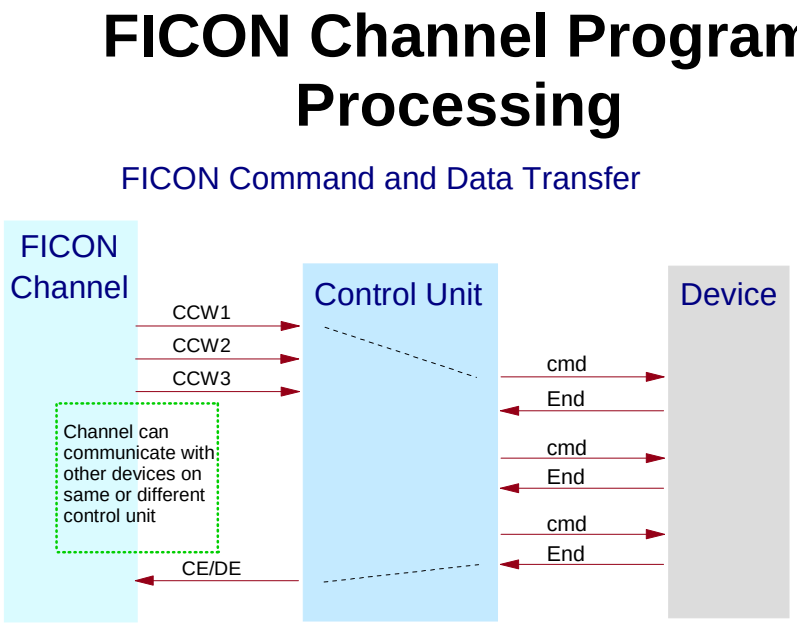


The channel program in this diagram contains 3 CCWs. The channel sends the first CCW to the control unit. The control unit performs command execution on this CCW and sends one or more commands to the device to instruct it to perform the requested function (only one device command is executed per CCW in this diagram). The device executes each command, one at a time, and then sends ending status for each to the control unit. The control unit takes the device's ending status and then sends control unit ending status to the channel. At this point the channel progresses to the next CCW in the chain and the previous scenario is repeated. Then, this sequence is repeated once more for the third and last CCW in the channel program.

The important point to note in this diagram is that the channel is throttled by the control unit and the device. The channel must "hand shake" on each CCW prior to moving ahead to the next. Also, the channel is completely dedicated to this connection and cannot communicate with any other control units until the entire channel program has completed, or when the control unit disconnects. In cases where the control unit and device incur large overheads in their command execution, the channel can be left idling and wasting precious CPU cycles.

The next diagram shows how FICON solves these problems.

In this diagram the same CCW chain as before is being executed on a FICON interface:



Note that with FICON the number of required "hand shakes" between the channel and the control unit has decreased from 3 down to 1. This is due to the fact that the FICON channel is allowed to stream all of the CCWs in the channel program to the control unit without any intermediate status or acknowledgment. This is sometimes called CCW Pipelining.

Also note that the FICON channel is allowed to communicate with other devices on the same or different control unit prior to the completion of this channel program. This is called multiplexing.

Configuring ESS for FICON Attachment

FICON is supported on the ESS "F" Model (not the "E" Model). When attaching an ESS "F" Model to a FICON interface, ESS host adapter feature codes 3021 and 3023 are used. Feature code 3021 is the long wave laser adapter which includes a 31 meter 9 micron cable with SC duplex connectors. This adapter is also supported with either the 50 or 62.5 micron multimode cable (ESCON cable) when mode conditioning cables are used at each end. Feature code 3023 is the short wave laser adapter which includes a 31 meter 50 micron cable with SC duplex connectors. This adapter is also supported with the 62.5 micron multimode cable. When these adapters are used for FICON attachment, they must be exclusively used for FICON and may not be shared with any FCP attachments.

Since this adapter takes up one of the four slots in one of the four I/O bays, you can have a maximum of 16 of these adapters in the ESS. This allows for a maximum of 16 FICON interface attachments. If these attachments are all point-to-point, then you can attach directly to 16 FICON channels; if some of these attachments are to switches, then you can attach to a maximum of 128 FICON channels per ESS FICON adapter (512 total per ESS), assuming that the switches are capable of attaching to this number of hosts. In addition, ESS allows 256 logical paths per FICON link (compared to just 64 for ESCON), 128 logical paths per Logical SubSystem (LSS), and 2048 logical paths per ESS.

Prior to the introduction of FICON on ESS, fibre channel connectivity was only available for FCP and only with a short wave laser adapter (feature code 3022). The new long wave laser adapter, combined with the 9 micron single mode fiber cable, increases the point-to-point distance capability from 500 meters to 10 kilometers (20 kilometers with an RPQ - Request for Price Quote). This longer distance capability is deemed to be extremely important in certain S/390 configurations.

System Attachment Considerations

There are a few important considerations that need to be understood in order to properly configure a system with FICON interfaces. The first is the number of equivalent ESCON links that can "fit" in a FICON link. That is, if the system were to require "x" ESCON links in order to get the performance and availability attributes that are desired, then how many FICON links will be required? Currently, with the performance work that has been performed so far, the expectation is that you can map 4 ESCON links to a single FICON link and maintain approximately equivalent performance. Note, though, that if the ESCON channel utilization is low, you can map up to 6 and possibly up to 8 ESCON links to a single FICON link. And, of course, for availability you will always want at least 2 FICON links.

The second consideration relates to multipathing and whether the rules for path groups are different for FICON compared to ESCON. In ESCON it is common to configure 4 or 8 paths per path group from a host to a storage subsystem. Should 4 or 8 paths per path group also be the rule for FICON? The correct answer is "No, the rules have changed." With ESCON you would want to have at least 4 paths in the path group just to reach adequate performance. This is because most of the ESCON control units implemented channel command execution that at least partially synchronized the lower DASD interface with the upper channel interface. This resulted in very tight timing windows for reconnections, which then resulted in some number of missed reconnections. Having at least 4 paths in the path group helped keep the number of missed reconnections down to a tolerable level. Going above 4 paths per path group did not substantially decrease the missed reconnections. The reason customers would use 8 paths in path groups was simply to increase the overall throughput.

With FICON control units, there is no longer any synchronization between the lower DASD interface and the upper channel interface. Therefore, the number of paths in the path group need only depend upon the throughput requirement. That is, if it takes "n" paths to satisfy the throughput requirement, then the path group should be set to "n". Of course, "n" must be a minimum of 2, and can't exceed the architected maximum of 8.

The third consideration concerns the number and type of control units that can be attached to a FICON channel, or a FICON channel path group. Attaching multiple control units to a channel is commonly referred to as "daisy-chaining". This term came from the S/360 OEMI parallel interface, where the interface cables would run from the channel to the first control unit, and then "daisy-chain" from the first control unit to the second, and from the second to the third, and so on.

With serial interfaces like ESCON and FICON we no longer "daisy-chain" the control units. However, when multiple control units are connected to a channel via a switch, it creates the logical equivalent of the parallel "daisy-chain". With the OEMI parallel interface and with the ESCON interface, whenever the channel and control unit communicated with each other, they formed a private connection. None of the other "daisy-chained" control units could communicate with the channel while this private connection was in place. The private connection could be supporting significant I/O between the channel and the control unit, OR it could be running

slowly, depending upon many factors affecting the control unit and device. The point is that the protocol did not allow any of the "daisy-chained" control units to use any "spare" cycles. This resulted in relatively poor actual performance compared to the interface's theoretical capability.

FICON changes the rules in this area. It does not support the private connection concept used in the previous interfaces. Instead, it performs frame (or packet) multiplexing. What this means is that in the configuration with the "daisy-chained" control units, the channel can be communicating with all of the control units simultaneously. It can multiplex its I/O operations across all of the control units at the same time. Therefore, no interface cycles need be wasted due to a private connection being in place. So with FICON it is OK to "daisy-chain" control units.

The next question though is whether or not it is OK to "daisy-chain" DASD control units with Tape control units. Tape generally performs much larger I/O operations at any instant in time. Therefore, even with FICON, when you have Tape I/O running, you can temporarily "lockout" some DASD I/O. Hence, it is still better to not put tape and DASD on the same FICON channel.

Attaching ESS to FICON Channels

The FICON adapters used in the IBM G5/G6 systems have feature codes 2314 and 2316 and are packaged with one port per adapter. Feature code 2314 is the long wave laser adapter; feature code 2316 is the short wave laser adapter. The FICON adapters used in the new z900 system have feature codes 2315 and 2318 and are packaged two ports per adapter. Feature code 2315 is called FICON LX and is the long wave laser adapter. Feature code 2318 is called FICON SX and is the short wave laser adapter. As with ESS, the long wave laser adapters are normally used with 9 micron single mode cable, but can be used with either 50 or 62.5 micron multimode cable (a.k.a. ESCON cable) when mode conditioning cables are attached at each end. The short wave laser adapters support the use of 50 and 62.5 micron multimode cable.

As stated previously, ESS can be attached directly to FICON channels or it can be attached to a Fibre Channel switch that is attached to FICON channels. When ESS is attached directly to FICON channels, then the maximum number of FICON attachments is 16, since that is the maximum number of host adapters that can be configured in ESS. Also, as stated previously, when an ESS host adapter is used to attach to FICON channels, either directly or through a switch, it is dedicated to FICON attachment and may not be simultaneously attached to FCP hosts.

When ESS is attached to FICON channels through one or more switches, then the maximum number of FICON attachments is 128 per ESS adapter. The fibre channel switches used for FICON traffic are being called "directors" by the switch manufacturers. The distinguishing features of these "directors" is that they are designed for very high availability with redundant components and no single points of failure or repair. We are qualifying both the McData and the Inrange directors for use with ESS for FICON attachment. These directors will support an in-band switch management function similar to what has been used with the ESCON directors.

Both of these directors are capable of attaching FCP hosts and devices in addition to the FICON hosts and devices. In these mixed configurations the FCP hosts should communicate only with the FCP devices and the FICON hosts should communicate only with the FICON devices. Although it is not required, it may be prudent to set up zones in the directors to guarantee that none of the FCP hosts or devices can affect the FICON traffic in any way.

When attaching FICON products to switches (or directors), it is important to note that switch cascading is not allowed. That is, you cannot configure a fabric of multiple interconnected directors and then have a FICON channel attached to one director communicate to a FICON control unit attached to another director. The current FICON architecture prohibits this capability. The reason for this restriction is because the base S/390 I/O architecture uses a single byte for addressing the I/O devices. This 1-byte I/O address is not compatible with Fibre Channel's 3-byte port address. The FICON solution to this problem is to disallow switch cascading.

FICON Configuration and Performance Considerations

The most obvious benefits of FICON connectivity are increased per channel bandwidth and greater simplicity of channel fabric. A single FICON channel supports up to 60 MB/sec sequential bandwidth which allows customers to collapse existing ESCON channels into FICON channels approximately 4:1, or in some cases more if ESCON channel utilizations are relatively low. So a well-configured ESS typically needs no more than eight FICON channel interfaces in order to fully exploit its bandwidth. Greater simplicity of configuration is also achieved because FICON architecture allows more devices per channel (up to 16,000) to match the increased channel bandwidth. Single stream sequential operations will enjoy dramatic improvement in throughput (as much as 2X), so that elapsed times for key batch, data mining, or dump operations will dramatically improve. This can provide relief for customers whose batch or file maintenance windows are constrained today.

IBM provides the following guidelines for planning FICON-connected ESS configurations:

- For ESCON channels with typical utilizations (25-50% today), plan one FICON channel for four ESCON channels. If channel utilization today is low (< 25%), you may be able to collapse more ESCON channels into each FICON channel, as many as 8:1. If your ESCON channels today are exceedingly busy (75% or greater), we recommend collapsing 2:1 to reduce channel utilization in the ultimate FICON environment.

- Plan minimally four channels per ESS. Fewer channels will not allow exploitation of full ESS bandwidth. A more typical configuration would have eight FICON channels for a 3.4 TB ESS.

- Spread FICON host adapters across all adapter bays. This should result in minimally one host adapter per bay, or in a typically configured ESS, two host adapters per bay.

- Define a minimum of four FICON channels per path group, as reflected in the IOCP/IODEF.

Response time improvements may accrue for some customers, particularly for data stored using larger blocksizes. The data transfer portion of response time is greatly reduced, because the data rate during transfer is roughly six times faster than ESCON. This improvement leads to significant connect time reduction. The larger the transfer, the greater the reduction as a percentage of the total I/O service time. Pend time caused by director port busy is totally eliminated because there are no more collisions in the director with FICON architecture. For customers whose ESCON directors are experiencing as much as 45-50% busy conditions this will provide significant response time reduction.

Simply stated, Parallel Access Volumes (PAVs) allow multiple concurrent I/Os to the same volume at the same time. Complementing this ability, FICON channels can process multiple concurrent data transfers, whereas ESCON channels process only one operation at a time. The maximum bandwidth of an individual RAID array within the ESS is approximately 45MB/s but the maximum bandwidth of an ESCON channel is only 17MB/s, hence a single ESCON channel

cannot exploit the maximum ability of the ESS arrays. PAVs and FICON work together to allow multiple data transfers to the same volume at the same time over the same channel, providing greater parallelism and greater bandwidth while simplifying configurations.

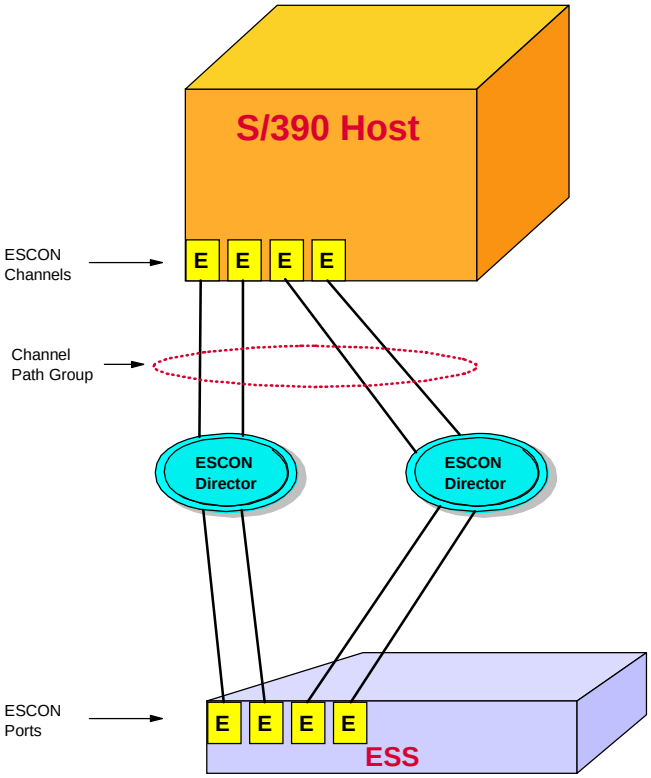
Another performance advantage delivered by FICON is that the ESS accepts multiple channel command words (CCWs) concurrently without waiting for completion of the previous CCW. This allows setup and execution of multiple CCWs from a single channel to happen concurrently. Moreover, I/O priority queuing is now handled at a "higher" point in the ESS system. Contention among multiple I/Os accessing the same data is now handled in the FICON host adapter, and queued according to the I/O priority indicated by the Workload Manager.

Finally, significant performance advantages will be realized by those customers who access their disk subsystems at distance. Multiplexing provides better bandwidth at distance. FICON eliminates data rate "droop" for distances up to 100 kilometers for both read and write operations by using enhanced data buffering and pacing schemes.

FICON thus extends the ESS' ability to deliver bandwidth potential to the logical volumes needing it, when they need it. Older technologies are limited by the bandwidth of a single disk drive or single ESCON channel, but FICON, RAID-5 and PAVs working together provide a high-speed pipe with multiplexed operations all the way down to your important data.

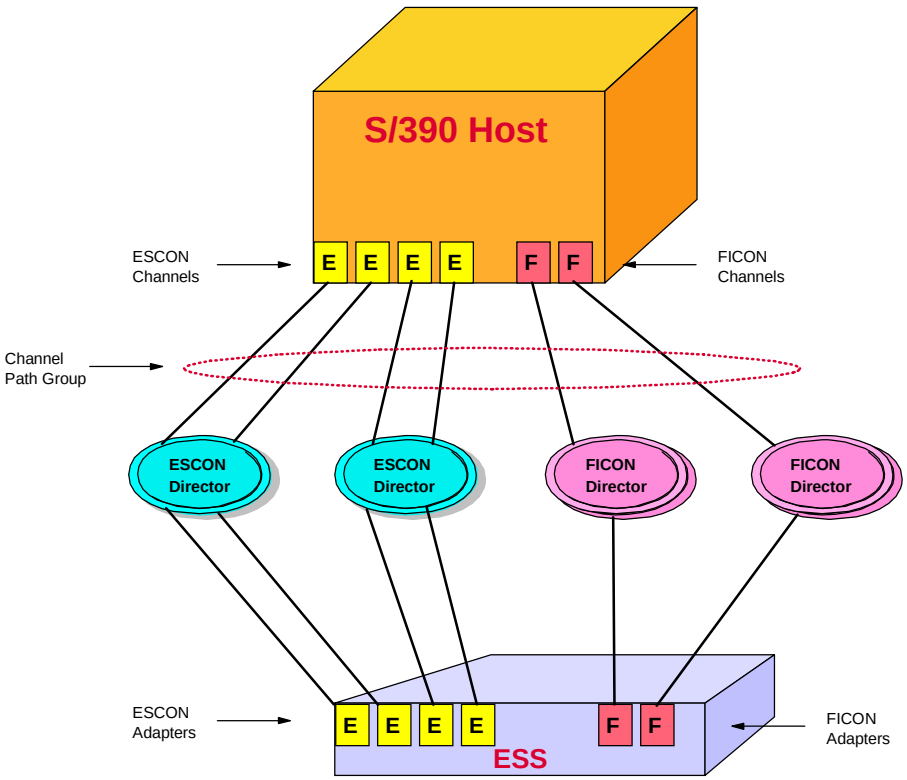
Migration From Native ESCON to FICON

As stated previously, FICON is only supported on the "F" Model of the ESS. So, assuming that you are starting with the "F" Model, migrating from a native ESCON configuration to a FICON configuration is fairly easy. The following diagram shows a sample native ESCON configuration. In this configuration the S/390 host has 4 ESCON channels attached to the ESS via 2 ESCON Directors. Also, these channels are grouped into a channel path group for multipathing capability.



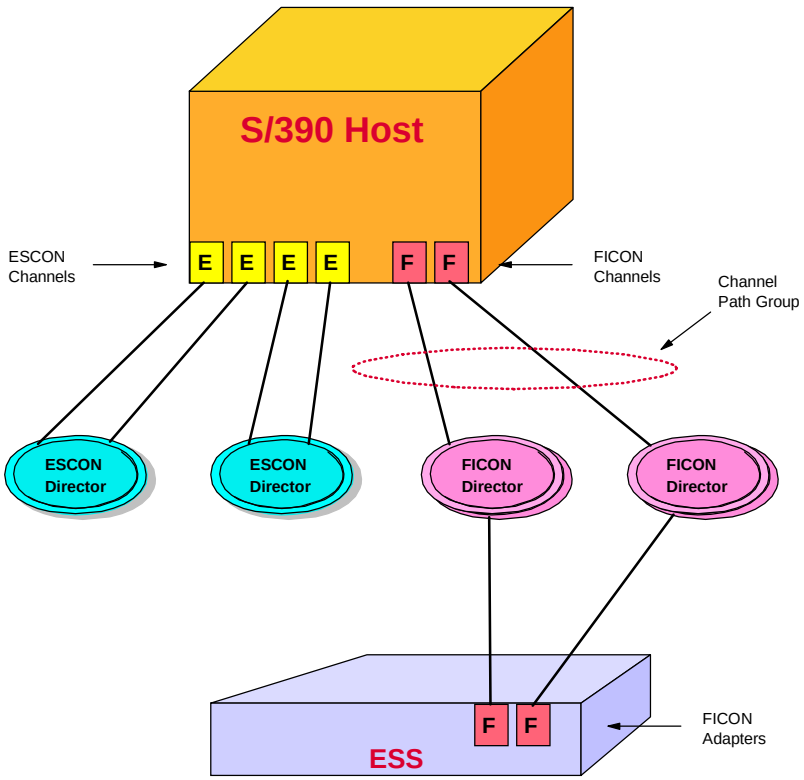
For this sample migration, the customer will be adding 2 FICON channels to his S/390 host and 2 FICON adapters to his ESS. If his operating system is not at the level that supports FICON, then he must upgrade to that level. Assuming the ESS is not at the level that supports FICON, he must apply the appropriate microcode upgrade to get that support.

In addition, he will be adding 2 FICON Directors. Note, though, that it is not necessary to use 2 FICON Directors. The customer could connect the FICON channels to the ESS FICON adapters directly, without any directors, or he could have just used a single director. I chose 2 directors in this example because it gives the customer the most flexibility for future I/O changes. These additions are shown in the following diagram:



Note in the above diagram that the newly added FICON channels have been added to the existing ESCON channel path group. The ability to have mixed channel path groups with both FICON and ESCON paths is what makes this migration so easy. It allows the customer to non-disruptively add FICON channels to his host and FICON adapters to the ESS. Once this is done the S/390 channel subsystem will start using the new FICON paths. Access to the devices on ESS are never disrupted.

The next step removes the ESCON paths. This is shown in the following diagram:



The ESCON adapters are non-disruptively removed from the ESS while all I/O continues on the FICON paths. Then the channel path group definition is changed to include just the FICON paths to complete the migration. The diagram shows the ESCON channels remaining on the S/390 host assuming that they would continue to be used to access other ESCON control units. Similarly, the ESCON adapters could have remained on the ESS for connectivity to other S/390 hosts.

Important Note Concerning the Mixed ESCON/FICON channel path group:

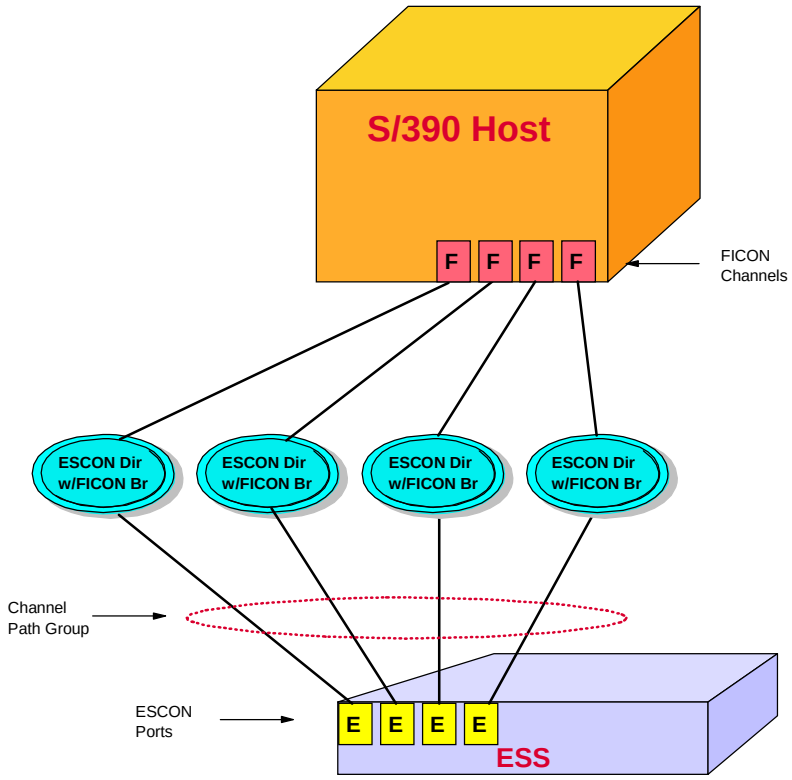
This capability is being supported by ESS for migration purposes only. It should not be used for any extended length of time. The reconnections for all devices with a mixed channel path group will be performed sub-optimally in order to guarantee that all operations execute properly. In addition, the internal performance measurements will be a combination of ESCON and FICON measurements and will not be meaningful. It is strongly recommended that the customer transition from the mixed channel path group configuration to an all FICON channel path group configuration as soon as possible.

Migration From FICON Bridge to FICON

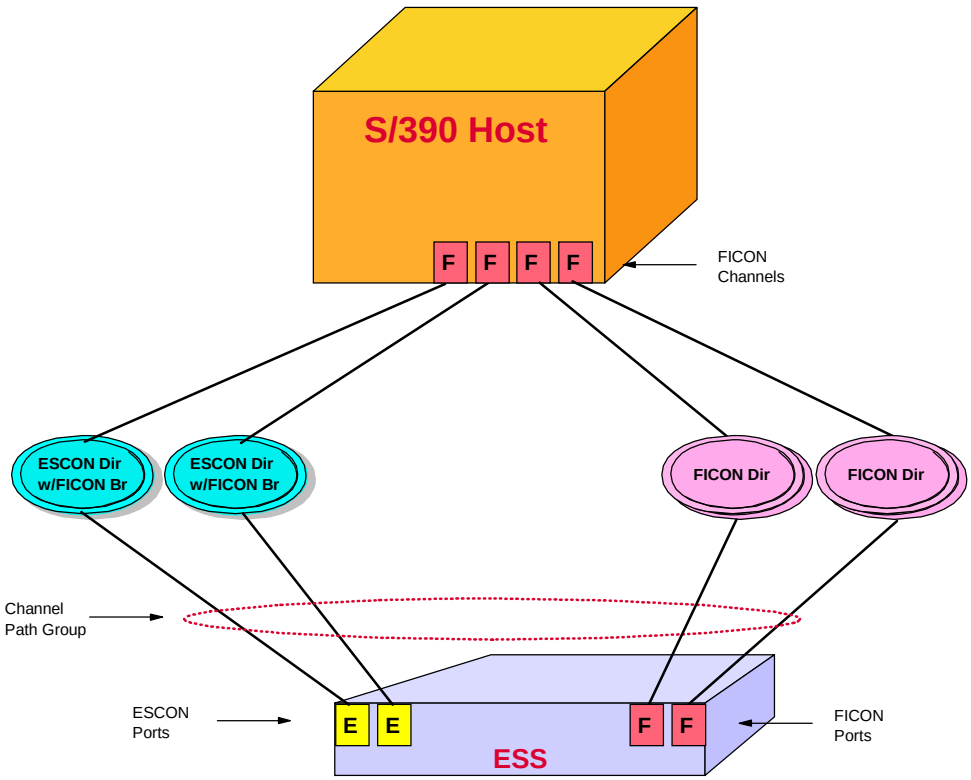
The migration from a configuration with a FICON bridge to native FICON is also quite simple.

The FICON bridge is a feature card of the ESCON Director 9032 Model 5. It supports an external FICON attachment and internally connects that FICON to a maximum of 8 ESCON links. The traffic of these ESCON links is multiplexed on the FICON link. The conversion between ESCON and FICON is performed on the bridge card.

The following diagram is a sample FICON bridge configuration. It shows an S/390 host with 4 FICON channels attached to 4 FICON bridges. The ESS is then attached to 4 ESCON links coming from the bridges. These 4 ESCON links are grouped into a channel path group.

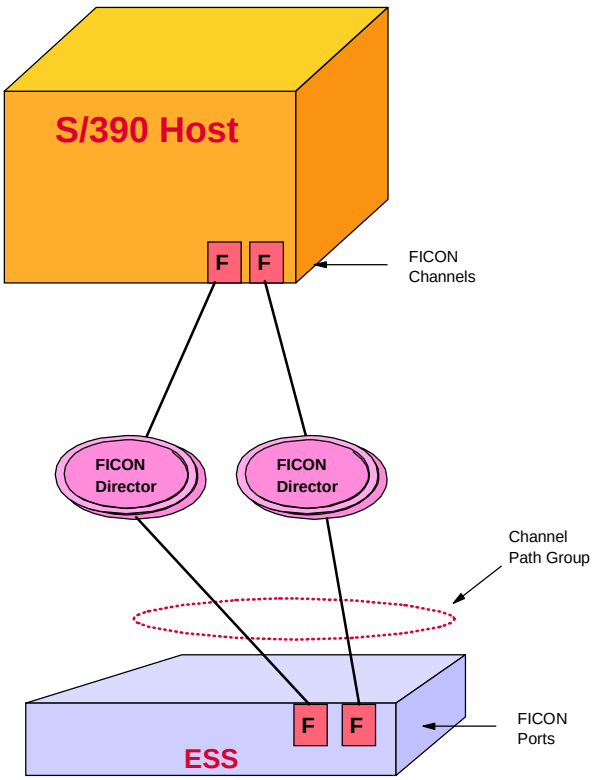


The first step in the migration to native FICON is to replace 2 of the FICON bridges with native FICON Directors and then to add 2 FICON host adapters to the ESS. This is shown in the following diagram:



The FICON channels that were connected to the bridges that were removed are reconnected to the new FICON Directors. The ESS FICON adapters are then connected to these new directors. As before in the migration from native ESCON to FICON, the channel path group is modified to include the new FICON paths. At this point the channel path group is a mixed ESCON/FICON path group, as described previously. I/O operations continue to the ESS devices across this mixed path group. Access to the ESS devices is never interrupted since all of these actions are non-disruptive.

The following diagram completes this migration:



The remaining bridges are removed leaving just the FICON paths. The migration is complete.

FICON Standardization

IBM initiated an effort to standardize the FICON interface in late 1998. As a result, an FC-SB-2 ad hoc work group was formed in December, 1998. FC-SB-2 is an abbreviation for Fibre Channel - Single Byte Command Code Set - 2. The S/390 channel interface has been referred to in the past as one which uses a "single byte command code". In fact, there was a direct mapping of the ESCON interface to Fibre Channel (never implemented, though) and it was called the FC-SB interface; thus the name FC-SB-2 is being used for FICON.

The first official meeting of the FC-SB-2 work group was held in April, 1999, with approximately 15 companies participating. The first draft of the proposed standard was completed in December, 1999. This draft was thoroughly reviewed and enhanced and subsequently forwarded for official approval within the T11 technical committee of the American National Standards Institute (ANSI). All public comments have been asked and answered. It is expected that official approvalThe total elaspsed time from the inception of FICON to the FC-SB-2 standard was 28 months.

References - Documents and Web Sites

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2. ESS User's Guide, SC26-7295, available from the following web site:
   http://www.ibm.com/storage/hardsoft/products/ess/refinfo.htm
3. ESS Web Interface User's Guide - Specialist, SC26-7346, available from the following web site:
   http://www.ibm.com/storage/hardsoft/products/ess/refinfo.htm
4. ESS Host Systems Attachment Guide, SC26-7296, available from the following web site:
   http://www.ibm.com/storage/hardsoft/products/ess/refinfo.htm
5. ESS Introduction and Planning Guide, SC26-7294, available from the following web site:
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6. ESS Configuration Planner, SC26-7353, available from the following web site:
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7. IBM Web Site for Supported Fibre Channel Server Configurations for the 2105 ESS:
   http://www.storage.ibm.com/hardsoft/products/ess/supserver
8. IBM Web Site for ESS Expert:
   http://SSDDOM01.storage.ibm.com/techsup/swtechsup.nsf/support/essfix

Notices

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