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A Deeper Look into the Inner Workings and Hidden Mechanisms of FICON Performance

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- Brocade Communications Inc.

- Thursday August 15, 2013 -- 9:30am to 10:30am

- Session Number - 14268

QR Code

SHARE in Boston

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I hope this helps in your educational efforts!

A deeper look into the Inner Workings and Hidden Mechanisms of FICON Performance

This technical session goes into a fairly deep discussion on some of the design considerations of a FICON infrastructure.

- Among the topics this session will focus on is:
  - Congestion and Backpressure in FC fabrics
  - How Buffer Credits get initialized
  - How FICON utilizes buffer credits
  - Oversubscription and Slow Draining Devices
  - Data Encoding and Forward Error Correction (FEC)
  - Virtual Channels for improved ISL Efficiency
  - Compression/Encryption on ISL links for Security and Efficiency

NOTE: Please check for the most recent copy of this presentation at the SHARE website as I make frequent updates.

This Section

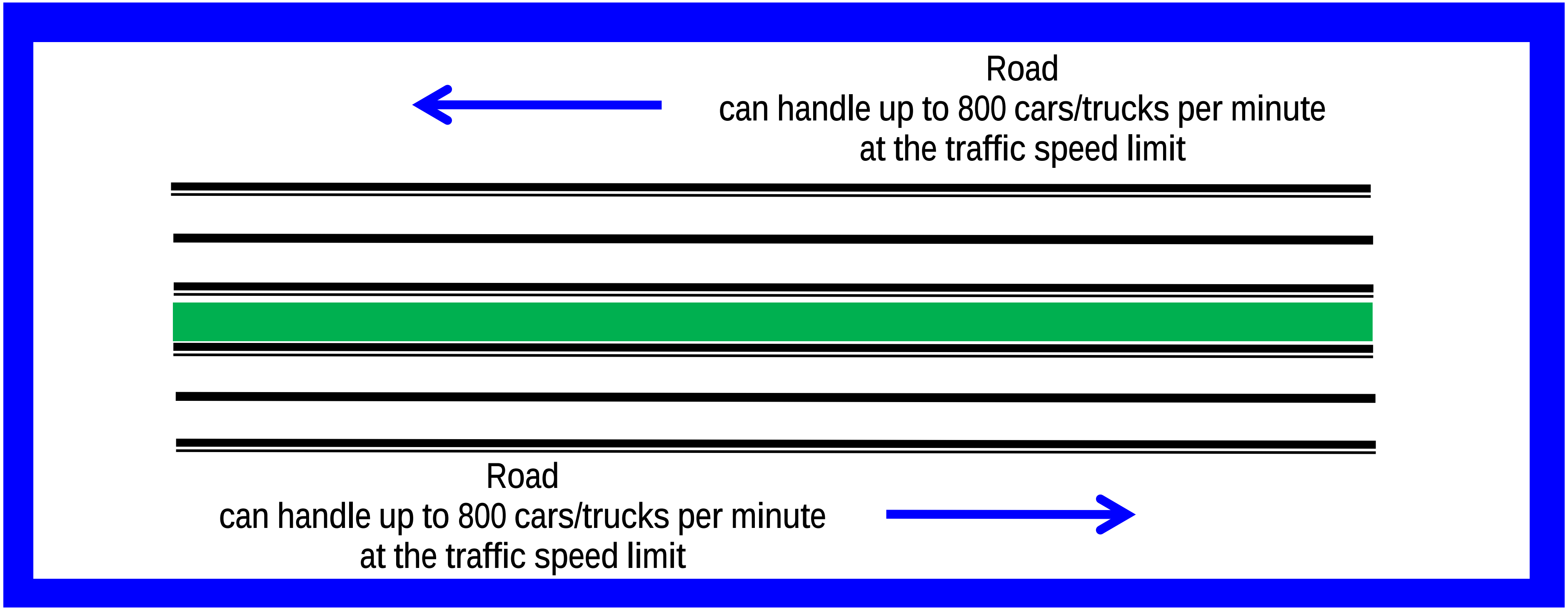
- Congestion and Backpressure Overview

Complete your sessions evaluation online at SHARE.org/BostonEval

Congestion and Backpressure Overview
These two conditions are not the same thing

- **Congestion** occurs at the point of restriction
- **Backpressure** is the effect felt by the environment leading up to the point of restriction

I will use an Interstate highway example to demonstrate these concepts



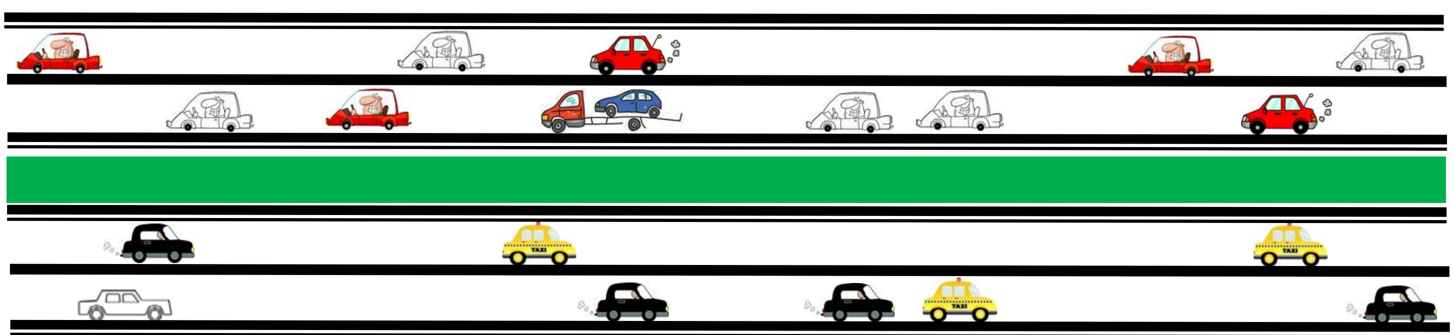
Congestion and Backpressure Overview

- **No Congestion and No Backpressure**
  - The highway handles up to 800 cars/trucks per minute and **less than** 800 cars/trucks per min are arriving
- Time spent in queue (behind slower traffic) is minimal
  - Cut-through routing (zipping along from point A to point B) works well

No Congestion and No Backpressure

10am – 3pm ←

Road
can handle up to 800 cars/trucks per minute
so the traffic can run up to the speed limit

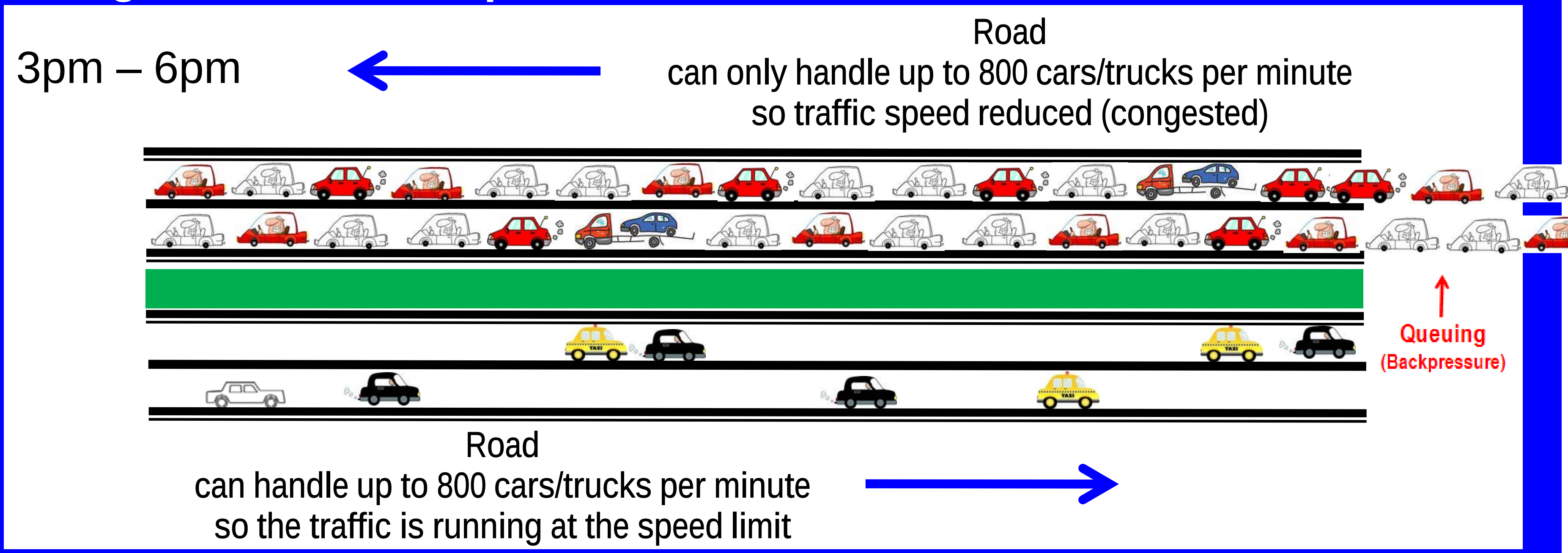


Road
can handle up to 800 cars/trucks per minute
so the traffic can run up to the speed limit →

Congestion and Backpressure Overview

- **Congestion**
  - The highway handles up to 800 cars/trucks per minute and **more than** 800 cars/trucks per min are arriving
- Latency time and buffer credit space consumed increases
  - Cut-through routing cannot decrease the problem
- **Backpressure** is experienced by cars slowing down and queuing up

Congestion and Backpressure



This Section

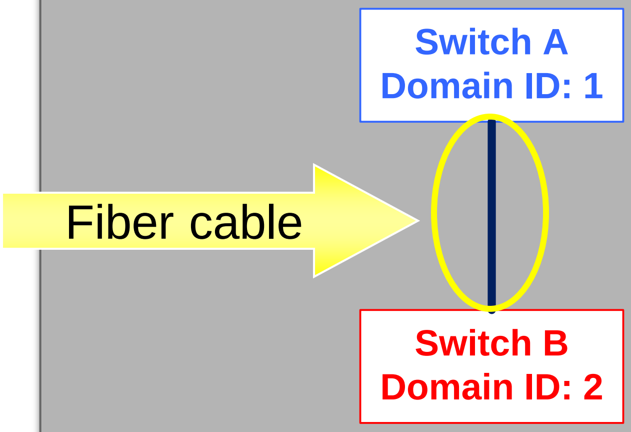
- Very basic flow for the Build Fabric process and how Buffer Credits get initialized

Build Fabric Process

Assume

- A fiber cable will be attached between switch A and B
- This will create an ISL (E_Port) between these two devices

Example Topology



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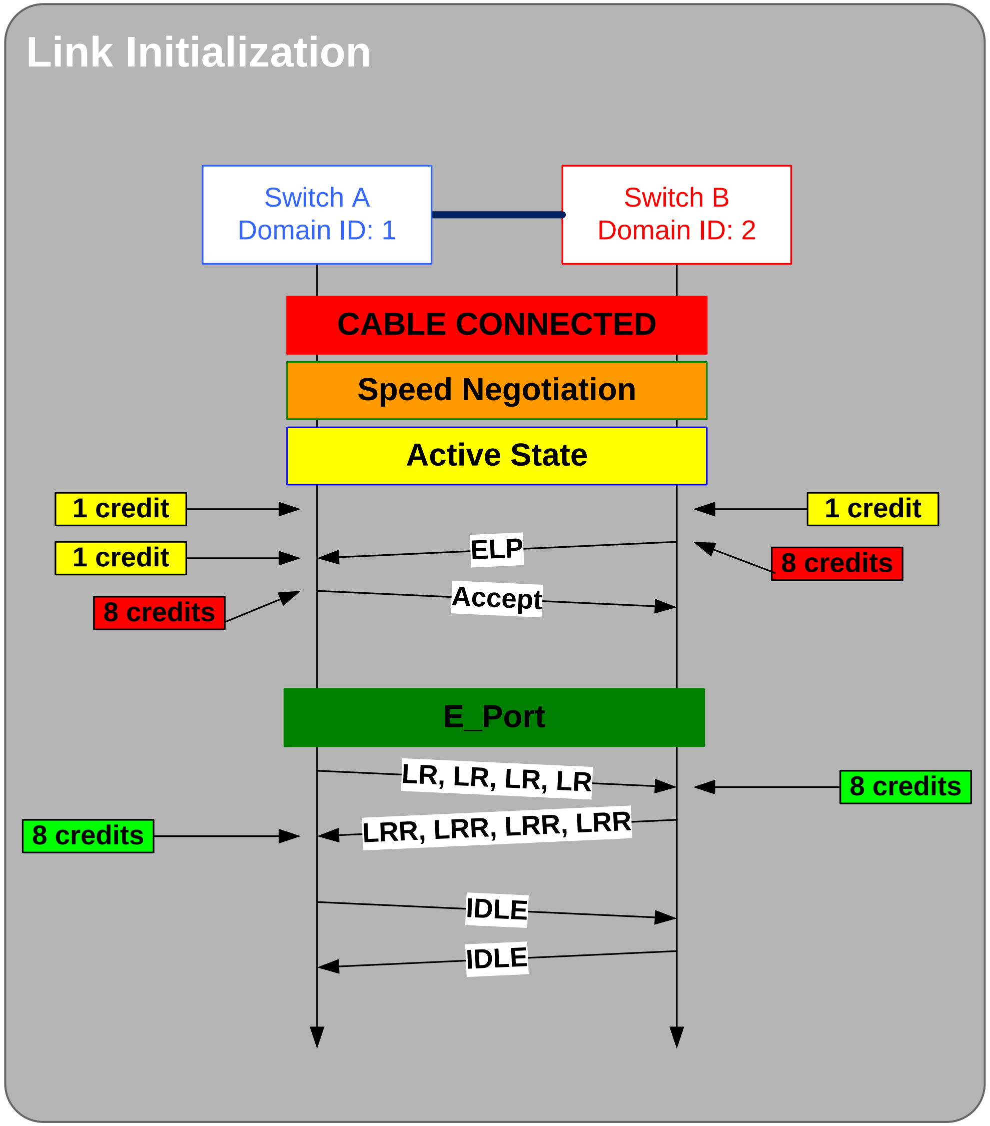
Build Fabric Process

- **Cable connected**
- **Link Speed Auto-Negotiation**
- **Link is now in an Active state**
- **One credit is granted by default to allow the port logins to occur**
- **Exchange Link Parms (ELP)**
  - Contains the "requested" buffer credit information for the sender
  - Assume 8 credits are being granted for this example
- **Responder Accepts – then does its own ELP**
  - Contains the "requested" buffer credit information for the responder
  - Assume 8 credits are being granted for this example
- **Link becomes an E_Port**
- **Send Link Resets (LR)**
  - Initializes Sender credit values
- **Link Reset Response (LRR)**
  - Initializes Responder credit values
- **Ready for I/O to start flowing**

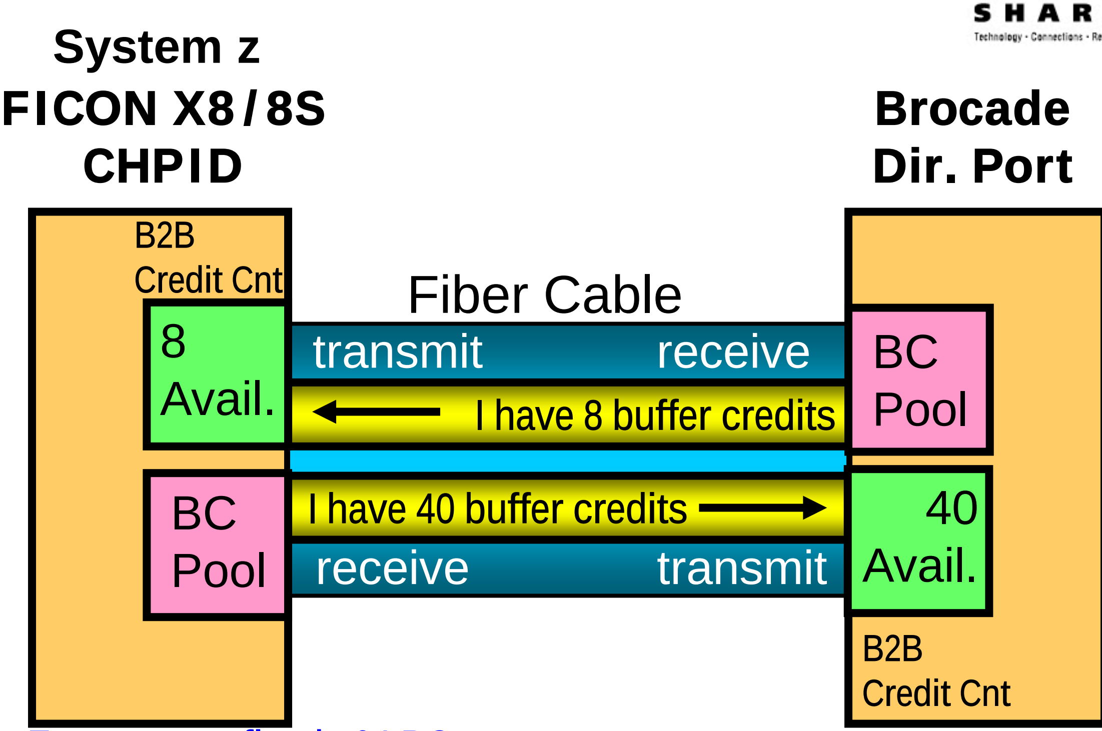


This Section

- How FICON uses Buffer-to-Buffer Credits
- Determining Buffer Credits Required
- RMF Reports for Switched-FICON
- Brocade's Buffer Credit Calculation Spreadsheet

How Buffer Credits Work

- A Fiber channel link is a PAIR of paths
- A path from "this" transmitter to the "other" receiver and a path from the "other" transmitter to "this“ receiver
- The "buffer" resides on each receiver, and that receiver tells the linked transmitter how many BB_Credits are available
- Sending a frame through the transmitter decrements the B2B Credit Counter
- Receiving an R-Rdy or VC-Rdy through the receiver increments the B2B Credit Counter
- DCX family has a buffer credit recovery capability



Express = fixed 64 BC
Express2 = fixed 107 BC
Express4 = fixed 200 BC
Express8 = fixed 40 BC
Express8S = fixed 40 BC

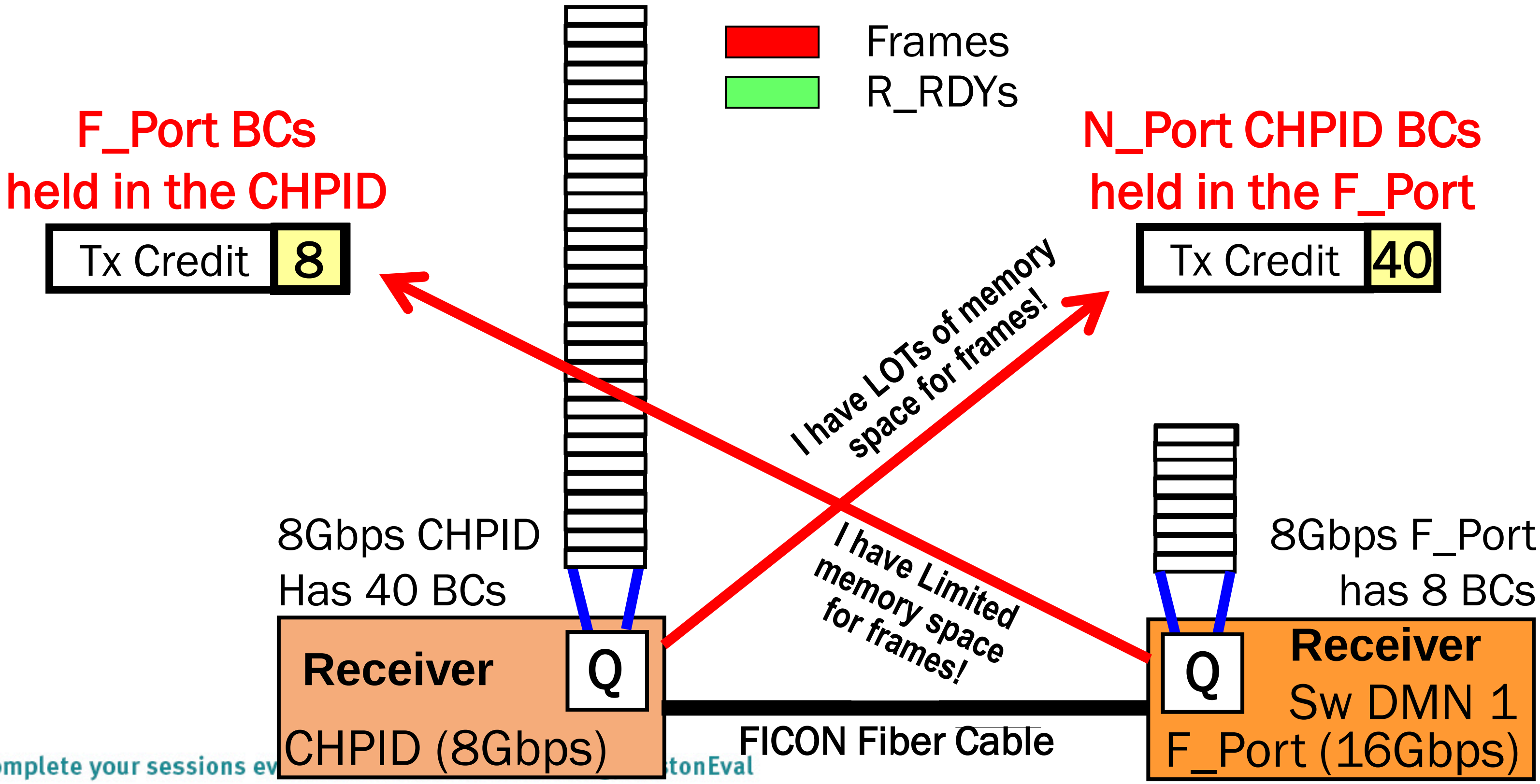
- Switch has variable BCs
- DASD has fixed BCs
- Old Tape had variable BCs

Each receiver on the fiber cable can state a different value!

Once established, it is transmit (write) connections that will typically run out of buffer credits

Buffer-to-Buffer Credits
Buffer-to-Buffer flow control

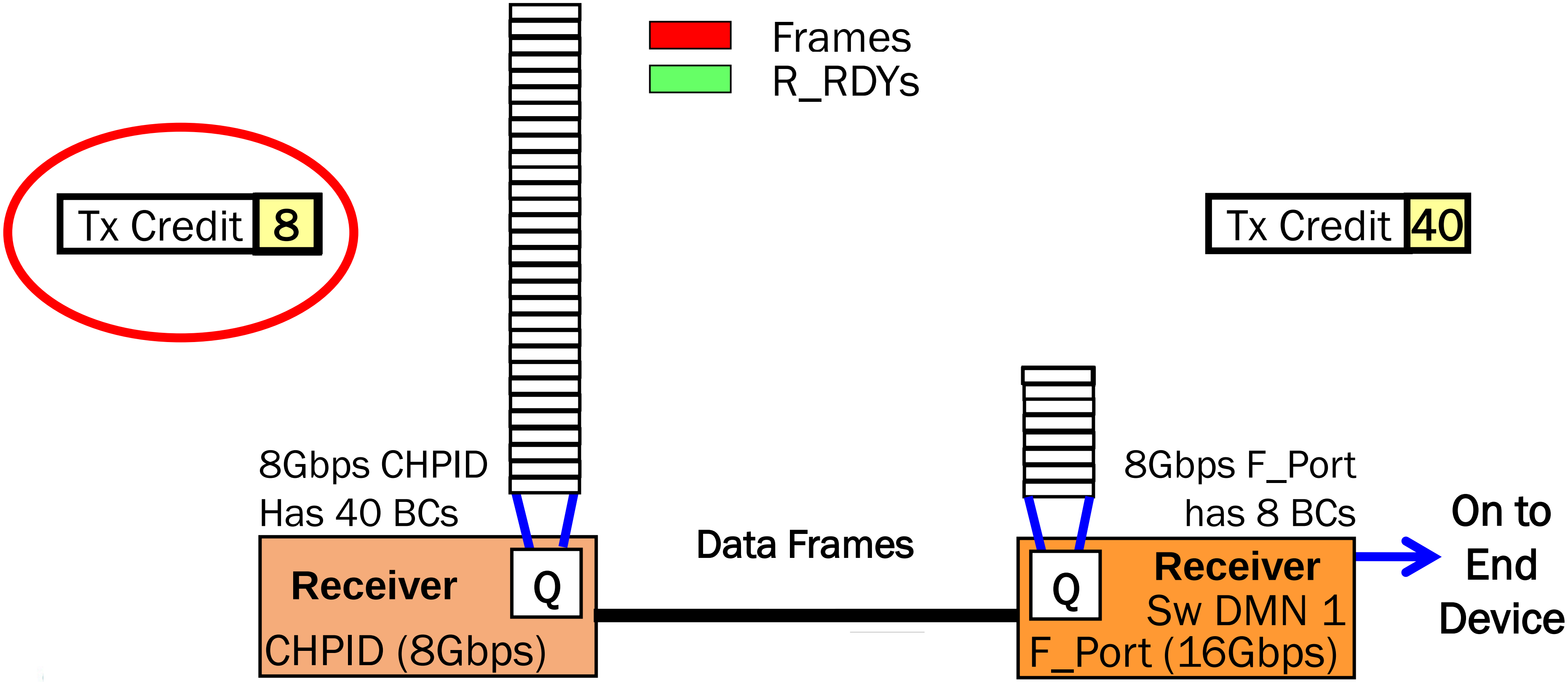
- After initialization, each port knows how many buffers are available in the queue **<u>at the other end of the link</u>**
  - This value is known as Transmit (Tx) Credit



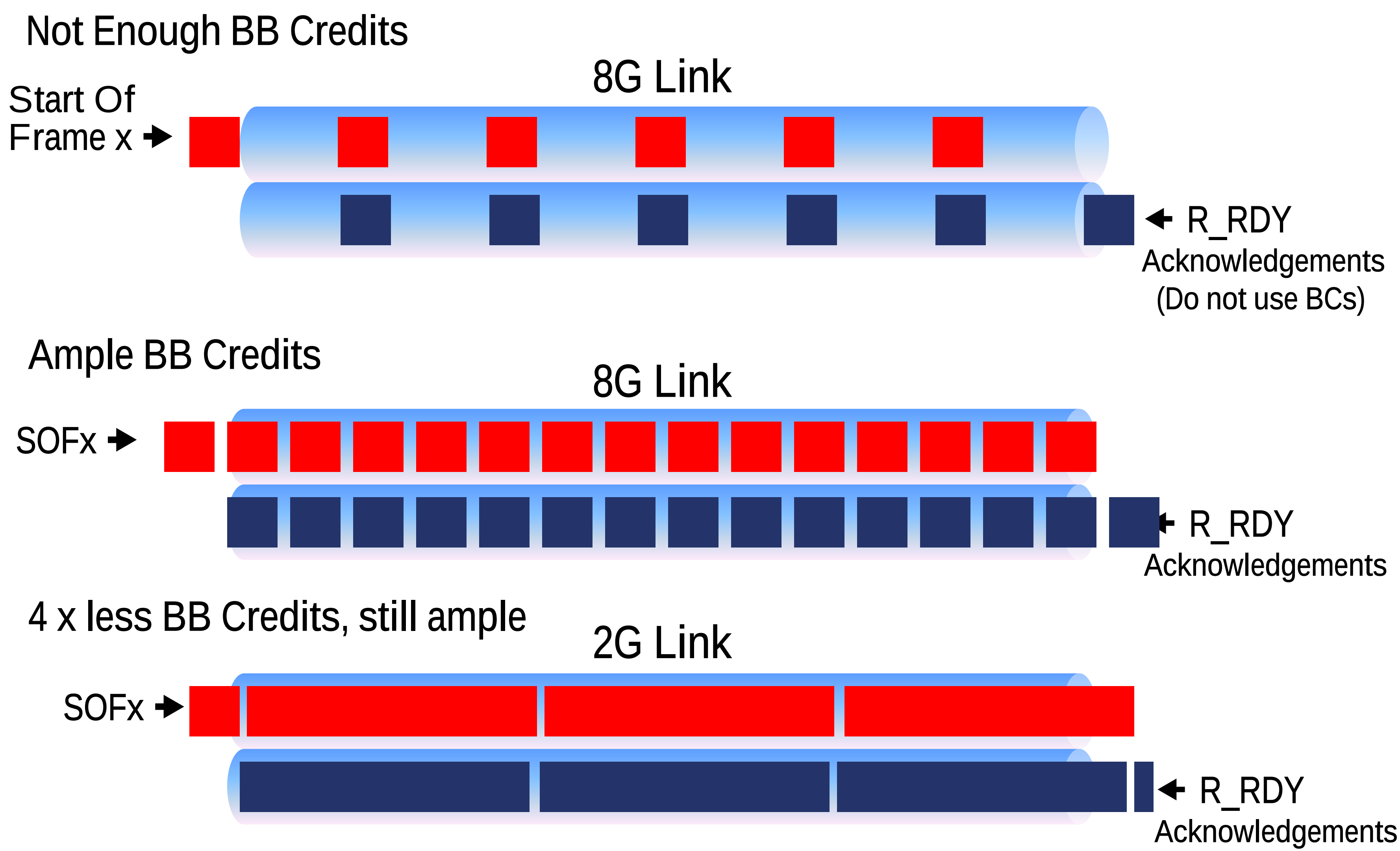
Buffer-to-Buffer Credits

Buffer-to-Buffer flow control Example

- Tx Credit is **decremented** by one for every frame sent from the CHPID
- No frames may be transmitted after Tx Credit reaches zero
- Tx Credit is **incremented** by one for each R_RDY received from F_Port



BB Credit Droop



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This Section

- Determining Buffer Credits Required
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Buffer Credits
Why FICON Never Averages a Full Frame Size

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- There are three things that are required to determine the number of buffer credits required across a long distance link
  - The speed of the link
  - The cable distance of the link
  - The average frame size
- Average frame size is the hardest to obtain
  - Use the RMF 74-7 records report “FICON Director Activity Report”
  - You will find that FICON just never averages full frame size
  - Below is a simple FICON 4K write that demonstrates average frame size

Control [44] Prefix Command
44 + 32 = 76B

4096 – 1984= 2112 | 2112 – 2048 = 64 | 64 + 4B IU CRC

Write (Payload) [1984 (-64B HDR)] [2048] [68]

2148 – 64 – 64 = 2020B | 2048 + 32 = 2084B | 68 +32 = 100B

Status Accept [36]
36 + 32 = 68B

4K will not fit into 2 BCs because of headers for FC as well as SB3 protocol that is used and the 64 byte FICON header that is placed into the payload field of the 1^{st} frame of every FICON exchange.

Average = (76+2020+2084+100+68) / 5 = 870 Bytes

Buffer Credits for Long Distance
The Impact of Average Frame Size on Buffer Credits

A distance of 20KM with 100% link utilization				2Gbps	4Gbps	8Gbps	10Gbps	16Gbps
SOF, Header, CRC, EOF	Payload	Total Frame Bytes	Smaller than full frame by xx%	Buffer Credis Required 8b10b	Buffer Credis Required 8b10b	Buffer Credis Required 8b10b	Buffer Credis Required 64b66b	Buffer Credis Required 64b66b
36	2112	2148	0.00%	20	40	80	99	159
36	1966	2002	6.80%	22	43	85	107	170
36	1824	1860	13.41%	23	46	92	115	183
36	1682	1718	20.02%	25	50	99	124	198
36	1540	1576	26.63%	27	54	108	135	216
36	1398	1434	33.24%	30	60	119	149	238
36	1256	1292	39.85%	33	66	132	165	264
36	1114	1150	46.46%	37	74	148	185	296
36	972	1008	53.07%	43	85	169	211	338
36	830	866	59.68%	50	99	197	246	393
36	688	724	66.29%	59	118	235	294	470
36	546	582	72.91%	74	147	293	366	585
36	404	440	79.52%	97	194	387	484	773
36	262	298	86.13%	143	286	571	714	1142
36	120	156	92.74%	273	545	1090	1363	2180
36	36	72	96.65%	591	1181	2362	2952	4724

Created by using Brocades Buffer Credit Calculator

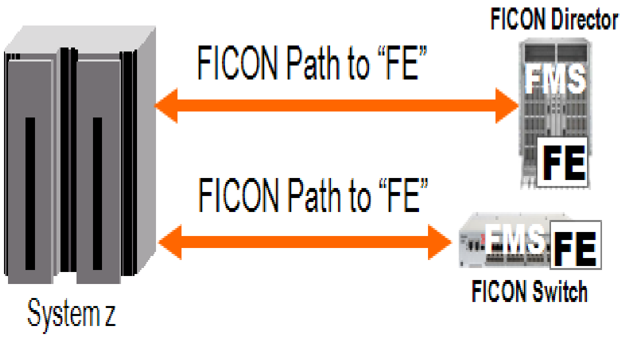
Buffer Credit Starvation
Why not just saturate each port with BCs?

- If a malfunction occurs in the fabric ….. or….
- If a CHPID or device is having a problem…
- It is certainly possible that some or all of the I/O will time out
- If ANY I/O does time out then:
  - All frames and buffers for that I/O (buffer credits) must be discarded
  - All frames and buffers for subsequently issued I/Os (frames and buffer credits) in that exchange must be discarded
    - Remember queued I/O will often drive exchanges ahead of time
  - The failing I/O must be re-driven
  - Subsequent I/O must be re-driven
- The recovery effort for the timed out I/O gets more and more complex – and more prone to also failing – when an over abundance of buffer credits are used on ports

Buffer Credit Starvation
Detecting Problems with FICON BCs

Produce the FICON Director Activity Report by creating the RMF 74-7 records – but this is only available when utilizing switched-FICON!

- A FICON Management Server (FMS) license per switching device enables the switch's Control Unit Port (CUP) – always FE – to provide information back to RMF at its request



- Analyze the column labeled AVG FRAME PACING for non-zero numbers. Each of these represents the number of times a frame was waiting for 2.5 microseconds or longer but BC count was at zero so the frame could not be sent

F I C O N   D I R E C T O R   A C T I V I T Y

PAGE 1

z/OS V1R8 SYSTEM ID PRD1 START 04/12/2009-04.30.00 INTERVAL 000.15.00
RPT VERSION V1R8 RMF END 04/12/2009-04.45.00 CYCLE 1.000 SECONDS
IODF = A2 CR-DATE: 03/27/2009 CR-TIME: 16.43.51 ACT: ACTIVATE
SWITCH DEVICE: 032B SWITCH ID: 2B TYPE: 006140 MODEL: 001 MAN: MCD PLANT: 01 SERIAL: 00000131656G

PORT	-CONNECTION-		AVG FRAME	AVG FRAME SIZE		PORT BANDWIDTH (MB/SEC)		ERROR
ADDR	UNIT	ID	PACING	READ	WRITE	-- READ --	-- WRITE --	COUNT
05	CHP	05	0	849	1436	8.63	17.34	0
07	CHP-H	6B	0	1681	1395	0.87	0.32	0
09	CHP	15	7	833	1429	11.96	20.49	0
0C	CHP-H	64	0	939	1099	0.39	0.50	0
0D	CHP	6B	1	1328	1823	3.56	12.73	0
0F	CHP-H	66	0	1496	1675	1.85	2.61	0
10	CHP	64	0	644	1380	0.03	0.13	0
13	CHP-H	19	0	907	885	0.58	0.45	0
16	CHP	12	0	1241	1738	0.97	1.72	0
17	CHP	0B	0	685	1688	0.10	0.82	0
1A	CHP	15	0	1144	1664	0.65	1.18	0
1B	CHP	0D	0	510	1759	0.12	1.72	0
1E	CHP-H	05	0	918	894	0.59	0.45	0
1F	CHP	21	0	1243	1736	0.97	1.70	0
20	CU	E900	0	1429	849	17.66	8.85	0
	CU	E800						
	CU	E700						
22	CHP	10	0	923	1753	0.55	2.78	0
23	CHP	54	0	1805	69	0.80	0.00	0
24	CHP	64	0	89	1345	0.00	0.00	0
27	CHP	6B	0	1619	82	0.01	0.00	0
28	CHP	95	27	918	1589	10.32	30.56	0
2B	CHP	70	0	69	2022	0.00	0.71	0

FICON Director Activity Report With Frame Delay

Using Buffer Credits is how FC does Flow Control, also called "Frame Pacing"

F I C O N   D I R E C T O R   A C T I V I T Y

PAGE 1

z/OS V1R8 | SYSTEM ID ABCD | START 04/12/2009-04.30.00 | INTERVAL 000.15.00

RPT VERSION V1R8 RMF | END 04/12/2009-04.45.00 | CYCLE 1.000 SECONDS

IODF = A2   CR-DATE: 03/27/2009   CR-TIME: 18.43.51   ACT: ACTIVATE

SWITCH DEVICE: 032B   SWITCH ID: 2B   TYPE: 006140   MODEL: 001   MAN: MCD   PLANT: 01   SERIAL: 0000HIJKLMN

PORT ADDR	-CONNECTION- UNIT	ID	AVG FRAME PACING	AVG FRAME SIZE READ	AVG FRAME SIZE WRITE	PORT BANDWIDTH (MB/SEC) -- READ --	-- WRITE --	ERROR COUNT
05	CHP-H	05	0	849	1436	8.63	17.34	0
07	CHP	6B	1	1681	1395	50.87	10.32	0
09	CHP	15	0	833	1429	11.96	20.49	0
0C	CHP-H	64	0	939	1099	0.39	0.50	0
0D	CHP	6B	0	1328	1823	3.56	12.73	0
0F	CHP-H	66	0	1496	1675	1.85	2.61	0
10	CHP	64	0	644	1380	0.03	0.13	0
13	CHP-H	19	0	907	885	0.58	0.45	0
16	CU	C800	0	1241	738	20.97	5.72	0
	CU	CA00				70.10	3.82	0
1A	CHP	15	0	1144	1664	0.65	1.18	0
1B	CHP	0D	0	510	1759	0.12	1.72	0
1E	CHP-H	05	0	918	894	0.59	0.45	0
1F	CHP	21	0	1243	1736	0.97	1.70	0
20	CU	E900	0	1429	849	17.66	8.85	0
	CU	E800						
	CU	E700						
22	CHP	10	0	923	1753	0.55	2.78	0
23	CHP	54	0	1805	69	20.80	7.30	0
24	CHP	64	0	89	1345	0.00	0.00	0
27	CHP	6B	0	1619	82	0.01	0.00	0
28	SWITCH	95	270	[illegible]	789	50.32	10.56	0
2B	CHP	70	0	69	2022	0.00	0.71	0

In the last 15 minutes

This port had a frame to send but did not have any Buffer Credits left to use to send them.

And this happened 270 times during the interval.

And this is an ISL Link!

Indicators of Buffer Credit Starvation

Fabric with zHPF Enabled

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We have a BC Calculator that you can use!

[illegible]	1/2 frame
[illegible]	1/3 frame
834	Typical DASD 4K

Brocade's Buffer Credit Calculation for Fibre Channel (FICON and/or SAN)

Parameter		Link Speed								
		1 Gbps	2 Gbps	4 Gbps	8 Gbps	10 Gbps	16 Gbps	32 Gbps	40 Gbps	100 Gbps
		1.0625E-09	2.1250E-09	4.2500E-09	8.5000E-09	1.0625E-08	3.4000E-08	1.3600E-07	3.4000E-07	1.0625E-06
Velocity of light in fibre	200000km/s	5.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-06	5.00E-06
Nano seconds per byte		9.41E-09	4.71E-09	2.35E-09	1.18E-09	9.41E-10	5.88E-10	2.94E-10	2.35E-10	9.41E-11
Framelength in seconds (dependent on cell I19)		8.19E-06	4.09E-06	2.05E-06	1.02E-06	8.19E-07	5.12E-07	2.56E-07	2.05E-07	8.19E-08
Framelength in km (dependent on cell I19)		1.64	0.82	0.41	0.20	0.16	0.10	0.05	0.04	0.02

10 Gig has 64b/66B en/decoding and therefore a better performance

Buffer Credit Calculation

To determine kilometers from miles, type miles into cell D19:
(1 mile = 1.609344 kilometer)

50 Miles Equals 80 Kilometers rounded to the nearest integer

To Calculate the proper number of buffer credits that you will need to keep the ISL link 100% utilized - especially over long distances:

Type in the frame "Payload" size in Bytes (in cell D23)=======> 834 Payload bytes and 36 overhead bytes equals a total frame size of 870 Bytes

Type in the total kilometers of the wire run (in cell D24)=====> 80 Kilometers
(Use the calculated kilometers from cell F19 if required)

If using 16G ISL compression, type in your compression Ratio (in cell F27)=====> 2.2 (2.2 to 1) (Compression and Encryption can reduce the frame size. Engineers suggest that compression will be 2 to 1. Unknown what encryption might do.)

Description	1 Gbps	2 Gbps	4 Gbps	Uncompressed 8 Gbps	Compressed 8 Gbps	Uncompressed 10 Gbps	Compressed 10 Gbps	Uncompressed 16 Gbps	Compressed 16 Gbps	Uncompressed 32 Gbps	Compressed 32 Gbps	Uncompressed 40 Gbps	Compressed 40 Gbps	Uncompressed 100 Gbps	Compressed 100 Gbps
Framelength takes up this many km on the wire (calculated from frame size in cell I20)	1.64	0.82	0.41	0.20	0.20	0.16	0.16	0.10	0.10	0.05	0.05	0.04	0.04	0.02	0.02
Buffercredits @ 100% B/W Utilization raw calculation:	97.72	195.44	390.88	781.76	1719.86	977.19	2149.83	1563.51	3439.73	3127.02	6879.45	3908.78	8599.31	9771.95	21498.28
Buffercredits @ 100% B/W Utilization rounded up:	98	196	391	782	1720	978	2150	1564	3440	3128	6880	3909	8600	9772	21499

1.) Condor3 ASICs can provide compression and/or encryption to any SFP that it hosts on a port -- (8Gb, 10Gb or 16Gb optics) for a user's ISL links
2.) Compression and/or encryption can be enabled or disabled as the user sees fit
3.) Compression and/or encryption is done on a frame-by-frame basis so when these are enabled there will be a need for additional buffer credits

Ask your local Brocade SE to provide this to you free of charge!

This Section

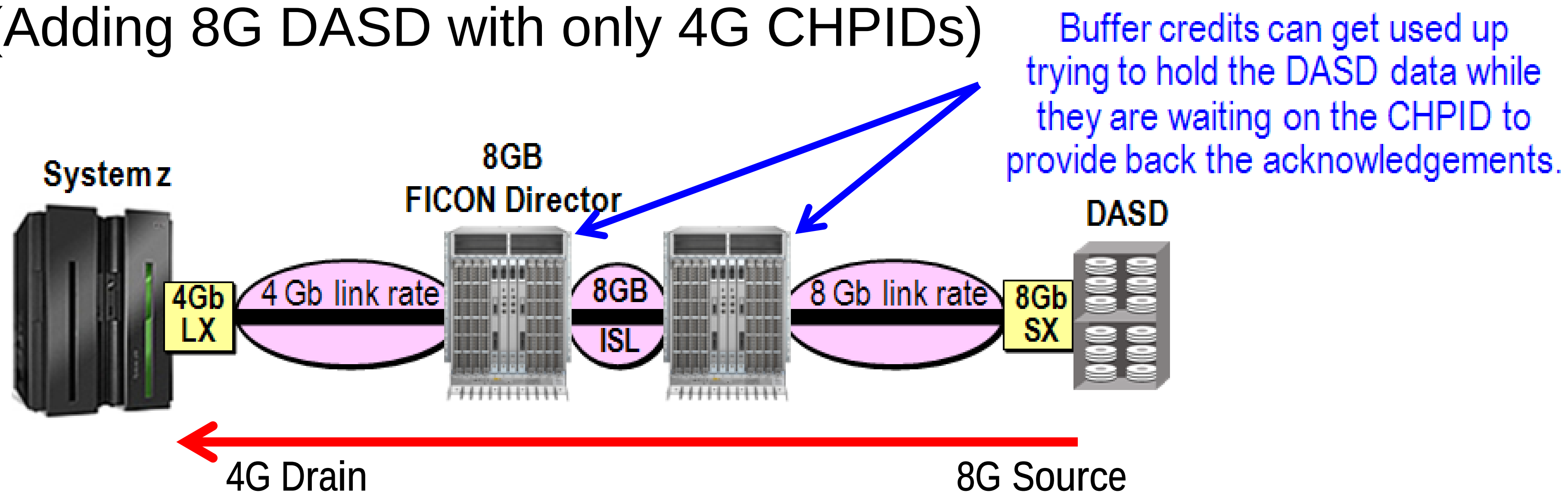
- Slow Draining Devices
- Data Encoding
- Forward Error Correction (FEC)
- Virtual Channels
- Compression and Encryption on ISLs

Slow Draining Devices

- Slow draining devices are **receiving ports** that have more data flowing to them than they can consume.
  - This causes external frame flow mechanisms to back up their frame queues and potentially deplete their buffer credits.
- A slow draining device can exist at any link utilization level
- It's very important to note that it can spread into the fabric and can slow down unrelated flows in the fabric.
- **What causes slow draining devices?**
- The most common cause is within the storage device or the server itself. That happens often because a target port has a slower link rate then the I/O source ports(s) or the Fan-In from the rest of the environment overwhelms the target port.

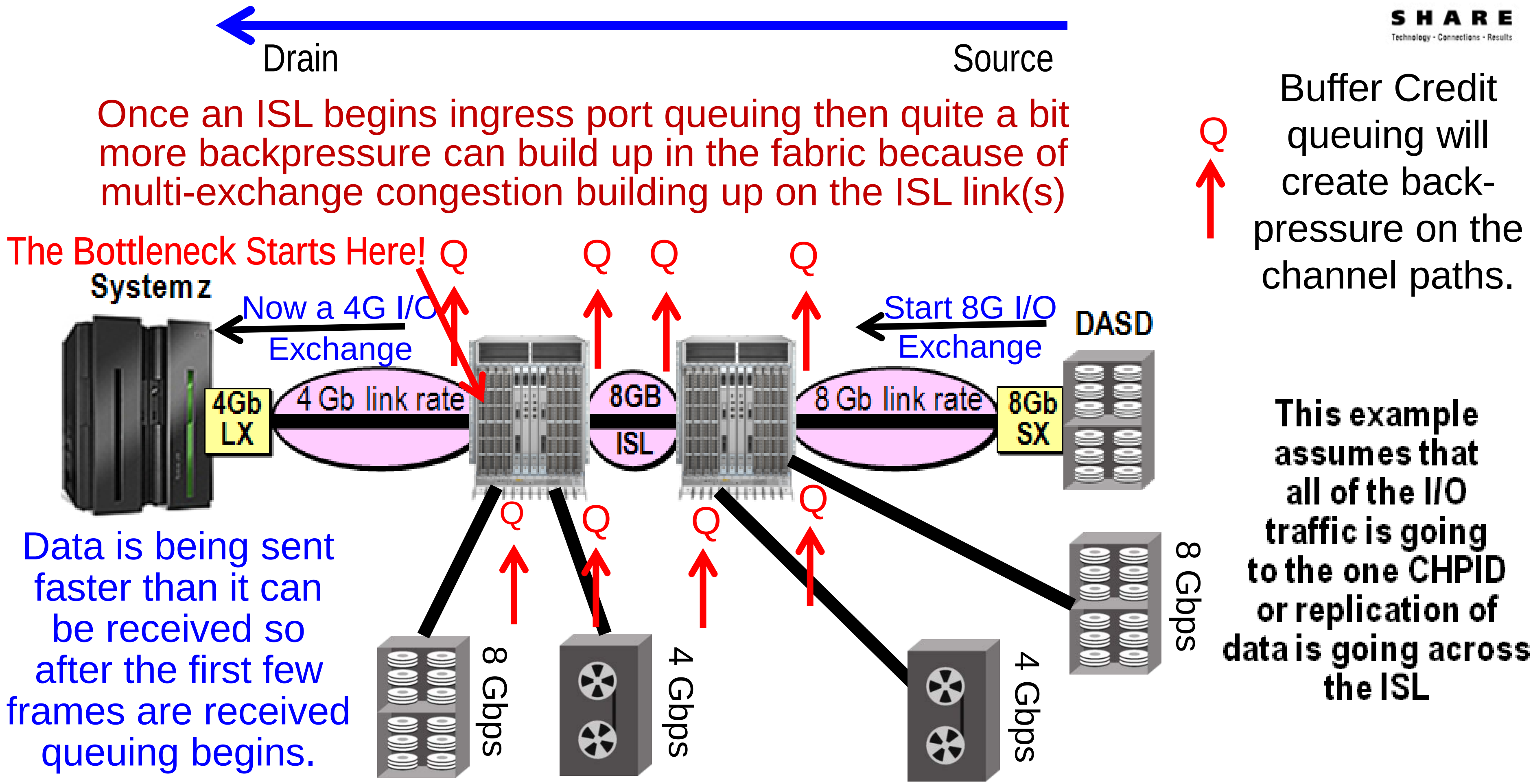
Slow Draining Devices – DASD

(Revisited from Session 13010)
(Adding 8G DASD with only 4G CHPIDs)



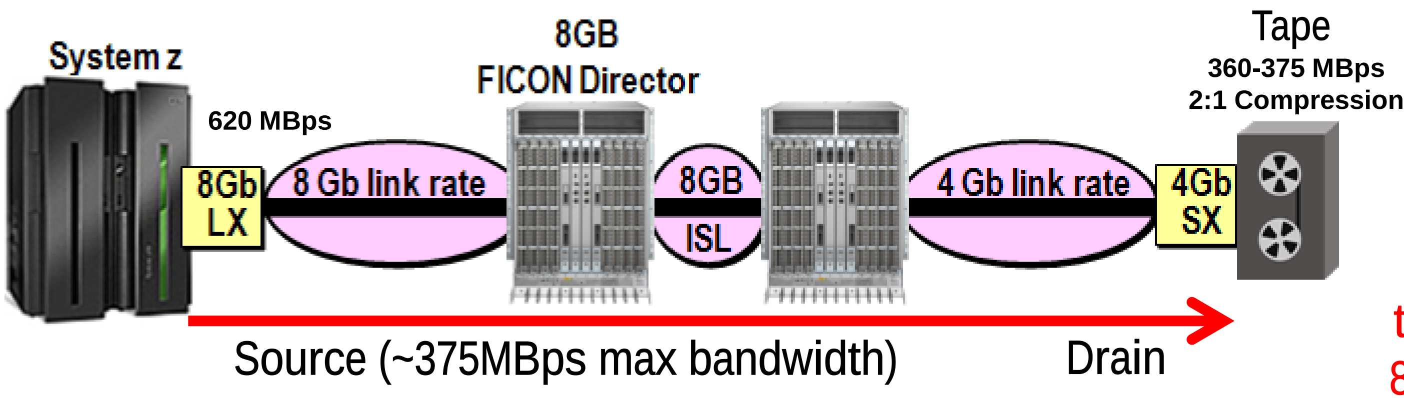
- This is potentially a very poor performing, infrastructure!
- DASD is about 90% read, 10% write. So, in this case the "drain" of the pipe is the 4Gb CHPID and the "source" of the pipe is the 8Gb storage port.
- The Source can out perform the Drain!
- This can cause congestion and back pressure towards the CHPID. The switch port leading to the CHPID becomes a slow draining device.

The Affects Of Link Rates (watch out for ISLs!)



- The is a simple representation of a single CHPID connection
- Of course that won't be true in a real configuration and the results could be much worse and more dire for configuration performance

Slow Draining Devices – Real Tape



BUT…
If 8G Tape runs at 375MBps (2X) it will take 750MBps to feed it and the best 8G CHPID <=620MBps

- For 4G tape this is OK – Tape is about 90% write and 10% read on average
- The maximum bandwidth a tape can accept and compress (@ 2:1 compression) is about 360MBps for Oracle (T1000C) and about 375MBps for IBM (TS1140)
- A FICON Express8S CHPID in Command Mode FICON can do about 620MBps
- A 4G Tape channel can carry about 380MBps (400 * .95 = 380MBps)
- So a single CHPID attached to a 4G tape interface:
  - Can run a single IBM tape drive (620 / 375 = 1.65)
  - Can run a single Oracle (STK) tape drive (620 / 360 = 1.72)

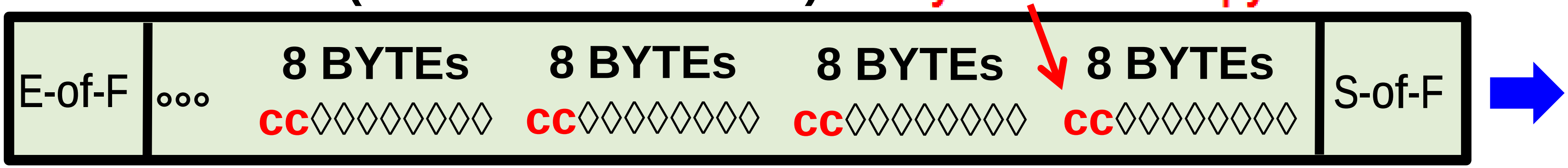
Data Encoding – Patented by IBM
8b/10b compared to 64b/66b

8b/10b (since 1950s but patented in 1983)

Payload Area of Frame – up to 2112 bytes of data

8b/10b: Each 8 bit Byte becomes a 10 bit Byte – 20% overhead

64b/66b (available since 2003) Sync Header – copy/save hi-order bit



Payload Area of Frame – up to 2112 bytes of data

64b/66b: Two check bits are added after every 8 Bytes – 3% overhead
- **At the end of every 32, eight byte groups, we have collected 32 hi-order ck bits**
- **This is a 32 bit check sum to enable Forward Error Correction to clean up links**

- 1/2/4 and 8Gbps will always use 8b/10b data encoding
- 10Gbps and 16Gbps will always use 64b/66b data encoding

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Forward Error Correction

Repairing Link Bit Errors using the Sync bits from 64b/66b encoding

- Dirty or worn cable links can cause bit errors in frames and even frame errors which, in the worst case, will drive I/O retry
- The 16 Gbps standard provides for a mechanism to correct ISL link bit errors – this new Brocade Gen 5 capability is called Forward Error Correction (FEC)
- Both sides of the ISL link must support 10 or 16 Gbps optics – not for DWDM or FCIP
- The high-order bits are collected from the 64b/66b data encoding to help correct transmission bit errors
- Used on our E_Ports (ISLs) that are Condor3-to-Condor3 ASIC connections
- Does slightly increase frame latency by about 400 nanoseconds per frame
- Significantly enhances reliability of frame transmissions and reduces I/O retries

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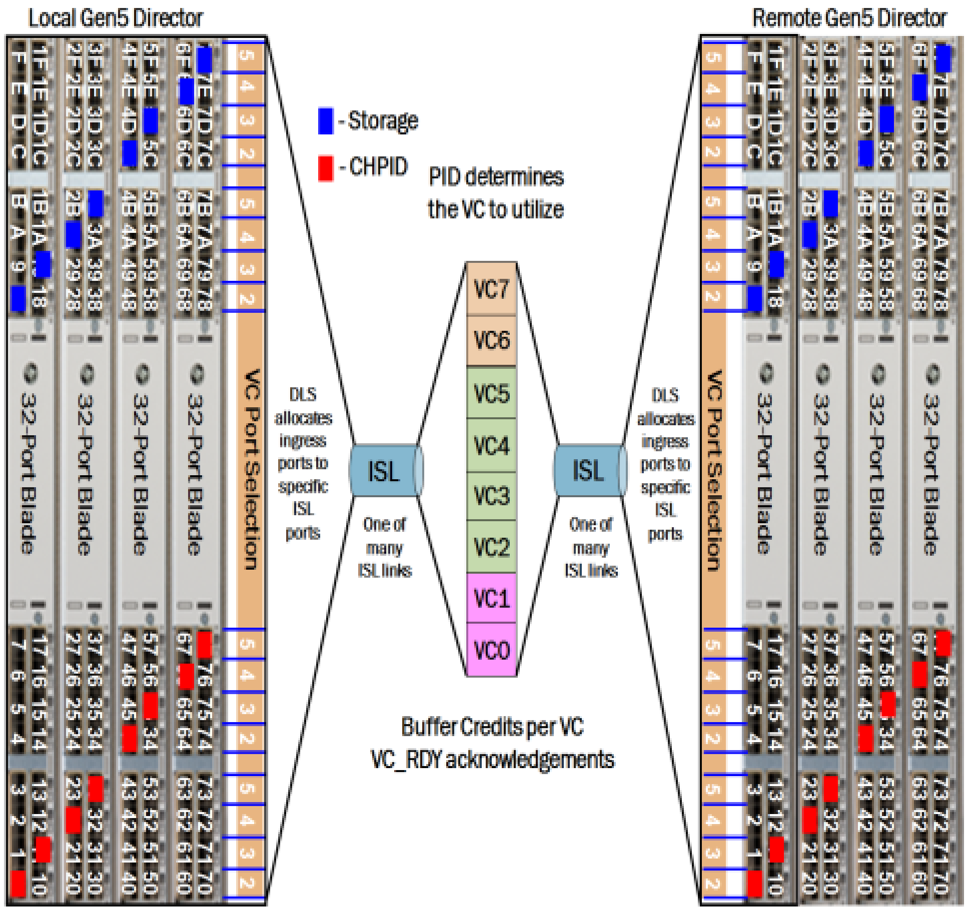
ISL Link Virtual Channels (VC)

Reduced Head-of-Line Blocking on ISL Links

- Reduced Head-of-Line Blocking (HoLB) on ISLs maximizes total switching fabric performance
- Brocade has been delivering a unique capability to minimize HoLB on ISL links as well as between fabric ports on a switch since 2002
- Virtual Channels can be thought of as several pools of buffer credits dedicated to an ISL port
- Each of these buffer credit pools (virtual channels) services unique F_Ports on each connectivity blade



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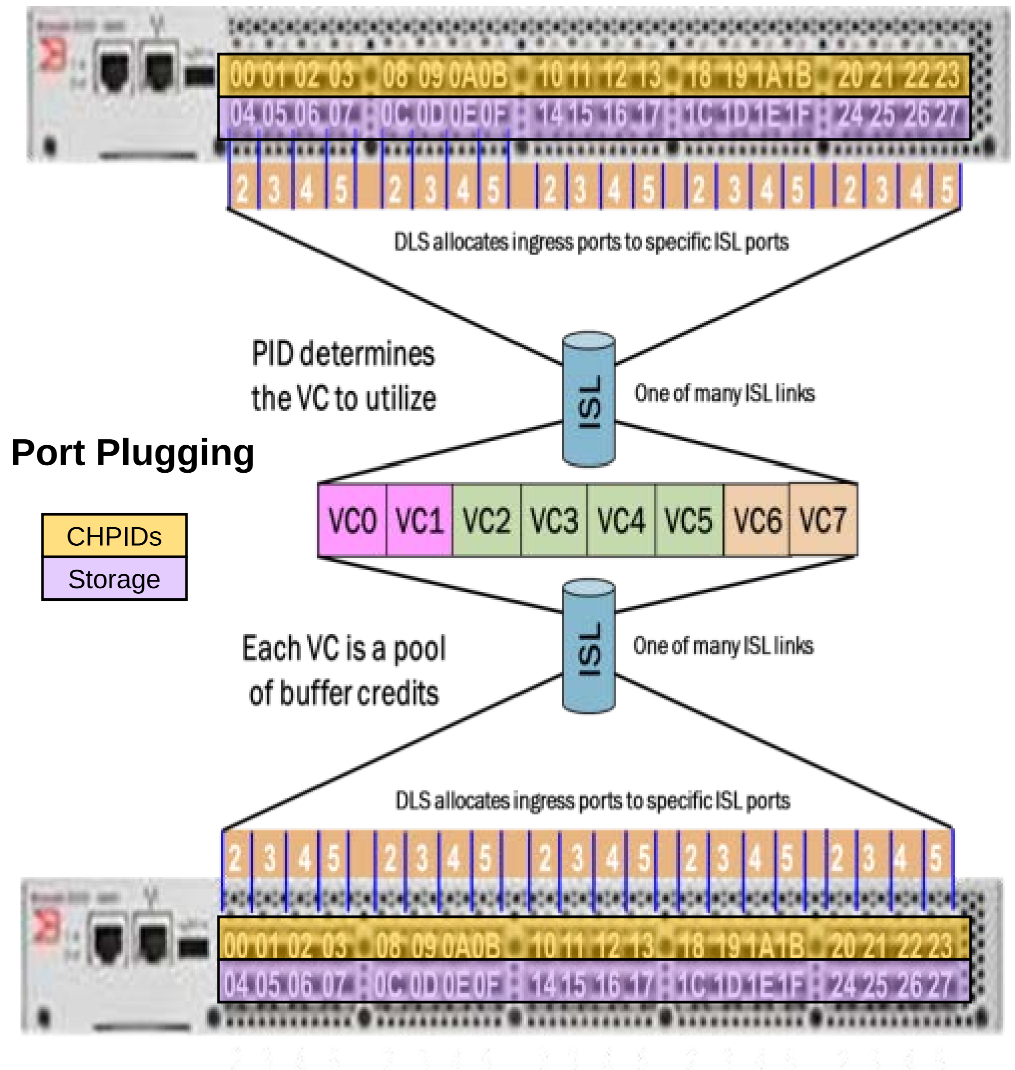
ISL Link Virtual Channels (VC)

Reduced Head-of-Line Blocking on ISL Links

- Works with any of Brocade's Gen2, Gen3, Gen4 and Gen5 switching devices.
- In this graphic it is easier to see how physical ports (PIDs) are mapped onto Virtual Channels (VC) when data will be sent across an ISL link
- Avoid using the same VC for both the source and destination traffic
  - Separate CHPIDs from their Storage Ports using different VCs where possible
  - This helps minimize HoLB



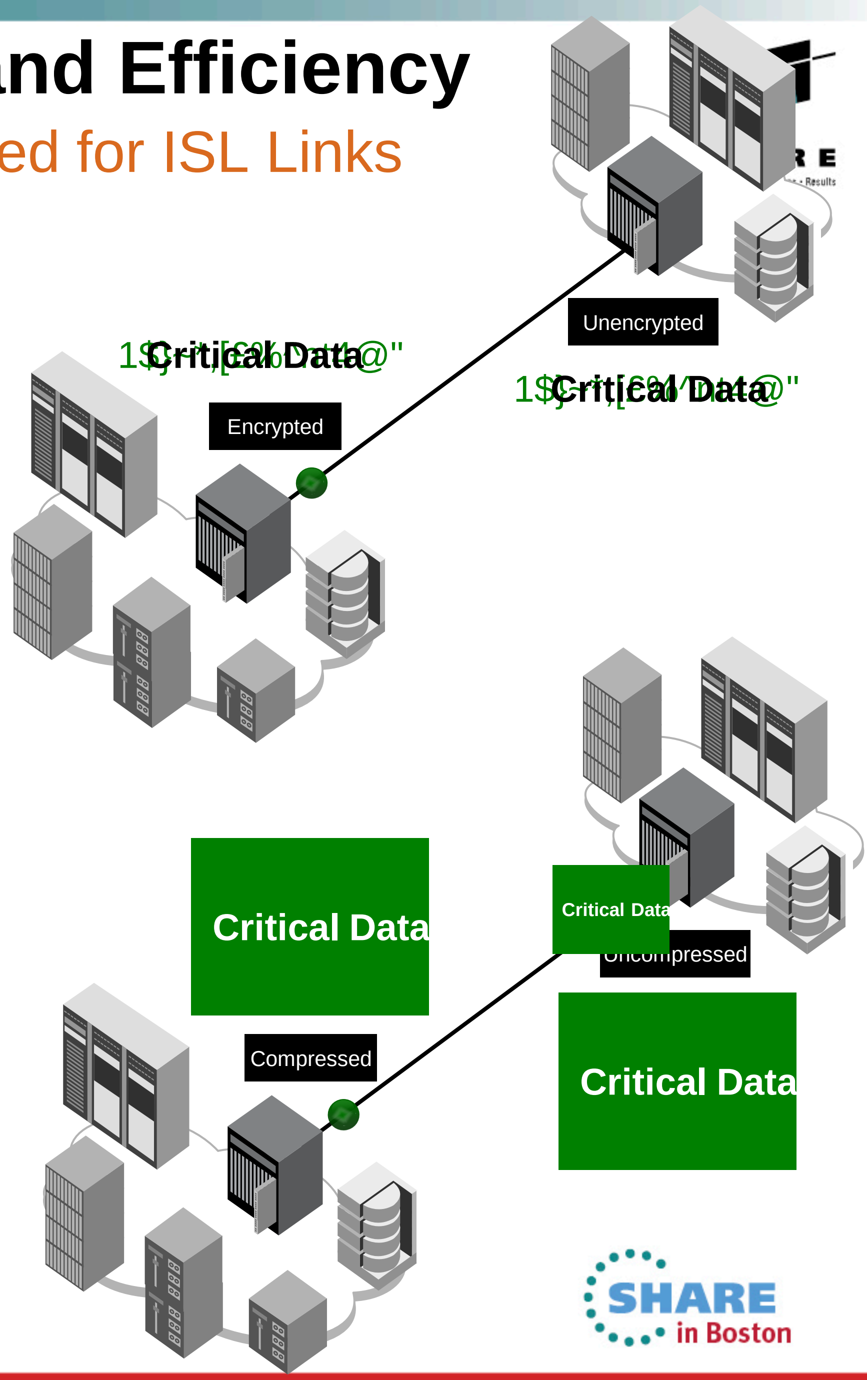
Improve Your ISL Security and Efficiency

Neither, Either or Both Can Be Specified for ISL Links

- **Secure Transfers**
  - Encrypts data on Brocade Gen 5 ISLs
    - Switch-to-switch in-flight encryption on the ISL link – not at-rest encryption
    - Useful over FC long-distance links
  - Uses AES-GCM algorithm for both authentication and encryption
  - Uses 256-bit encryption key

- **Maximum Network Efficiency**
  - Disk or tape traffic gets compressed on ISL and gets uncompressed at the receiving switch
  - In-flight compression of data only
  - Provides up to 2:1 compression and uses Brocade LZO algorithm
  - Provides up to 128 Gbps of compressed bandwidth per blade

- **No licenses required**



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Brocade Certified Architect for FICON

- Certification for Brocade Mainframe-centric Customers
- Available since September 2008
- Updated for 8Gbps in June 2010
- Updated for 16Gbps in November 2012
- This certification tests the attendee's ability to understand IBM System z I/O concepts, and demonstrate knowledge of Brocade FICON Director and switching infrastructure components
- ***Brocade would be glad to provide a free 2-day BCAF certification class for Your Company or in Your City!***
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This FICON Certification is Unique in the Industry

BCAF is a Preparatory Certification Seminar – 2 days

- These classes teach the certification material
- Certification is awarded only after successful completion of the examination
- We have been holding classes since mid-2008
- This is good for mainframers who desire to become professionally certified as FICON subject matter experts
- This uses advanced materials and is not well suited for professionals with less than 1 year of experience

Total number of attendees at these seminars since 2008: **455** (as of May 2013)

Total number of Brocade FICON Certifications awarded: **222+**

We also have a Brocade Accredited FICON Specialist credential (based on WBT training and an exam): **122** awarded

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Your Eval

My Reaction!

5: "Aw shucks. Thanks!"
4: "Mighty kind of you!"
3: "Glad you enjoyed this!"
2: "A Few Golden Nuggets!"
1: "You Got a nice nap!"

Thursday August 15, 2013 -- 9:30am to 10:30am -- Session 14268