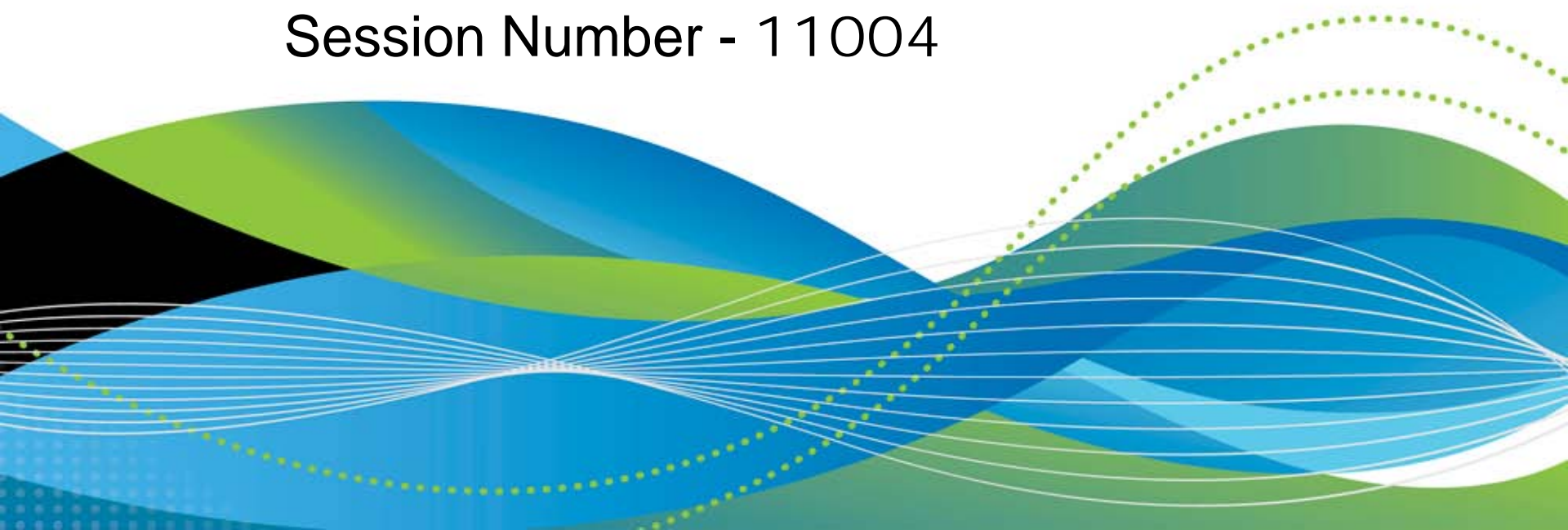


A Deeper Look into the Inner Workings and Hidden Mechanisms of FICON Performance

David Lytle, BCAF
Brocade Communications Inc.

Tuesday March 13, 2012 -- 3pm to 4pm

Session Number - 11004



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I have saved the PDF files for my presentations in such a way that all of the audience notes are available as you read the PDF file that you download.

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This will usually give you more information than just what the slide contains.

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
 - Determining Buffer Credit Requirements
 - FICON RMF Reporting

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



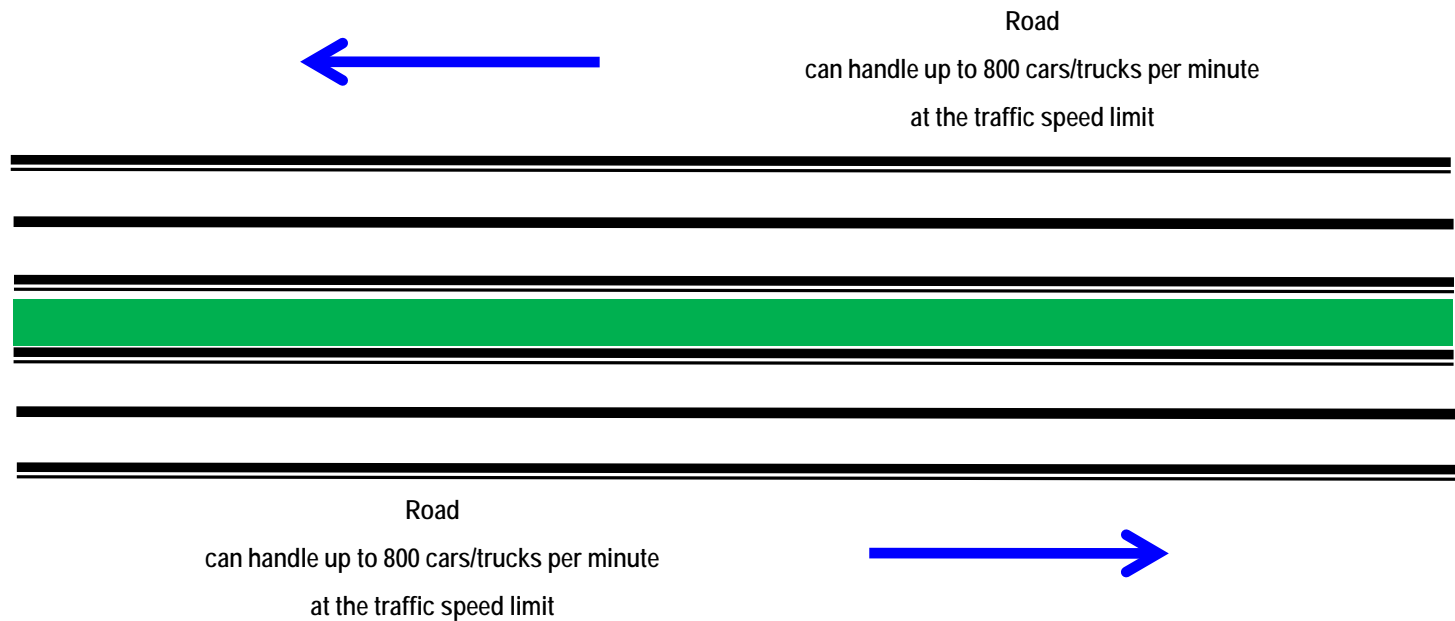
Congestion and Backpressure Overview

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

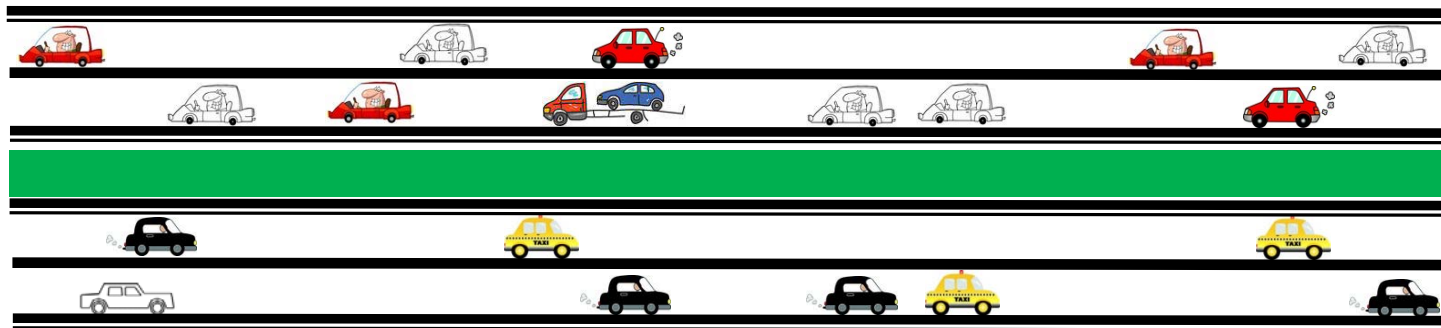
No Congestion and No Backpressure

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

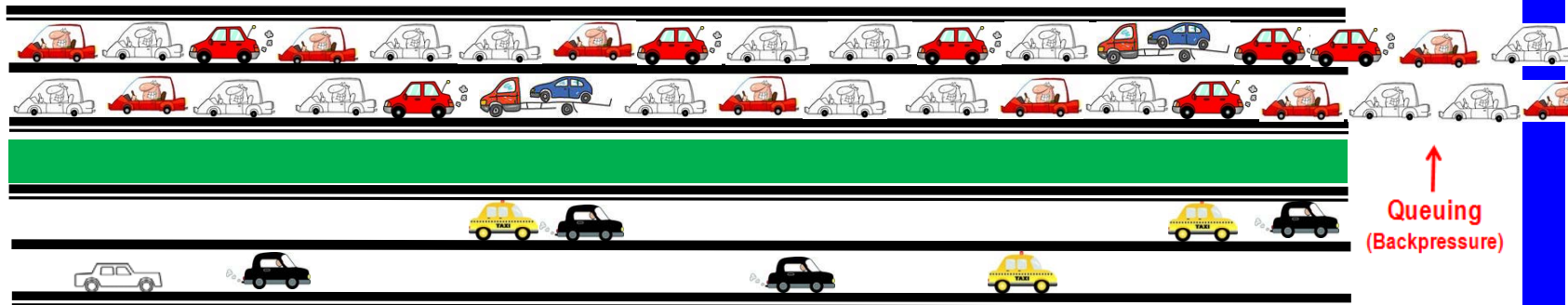
Congestion and Backpressure

3pm – 6pm



Road

can only handle up to 800 cars/trucks per minute
so traffic speed reduced (congested)



↑
Queuing
(Backpressure)

Road

can handle up to 800 cars/trucks per minute
so the traffic is running at the speed limit



This Section

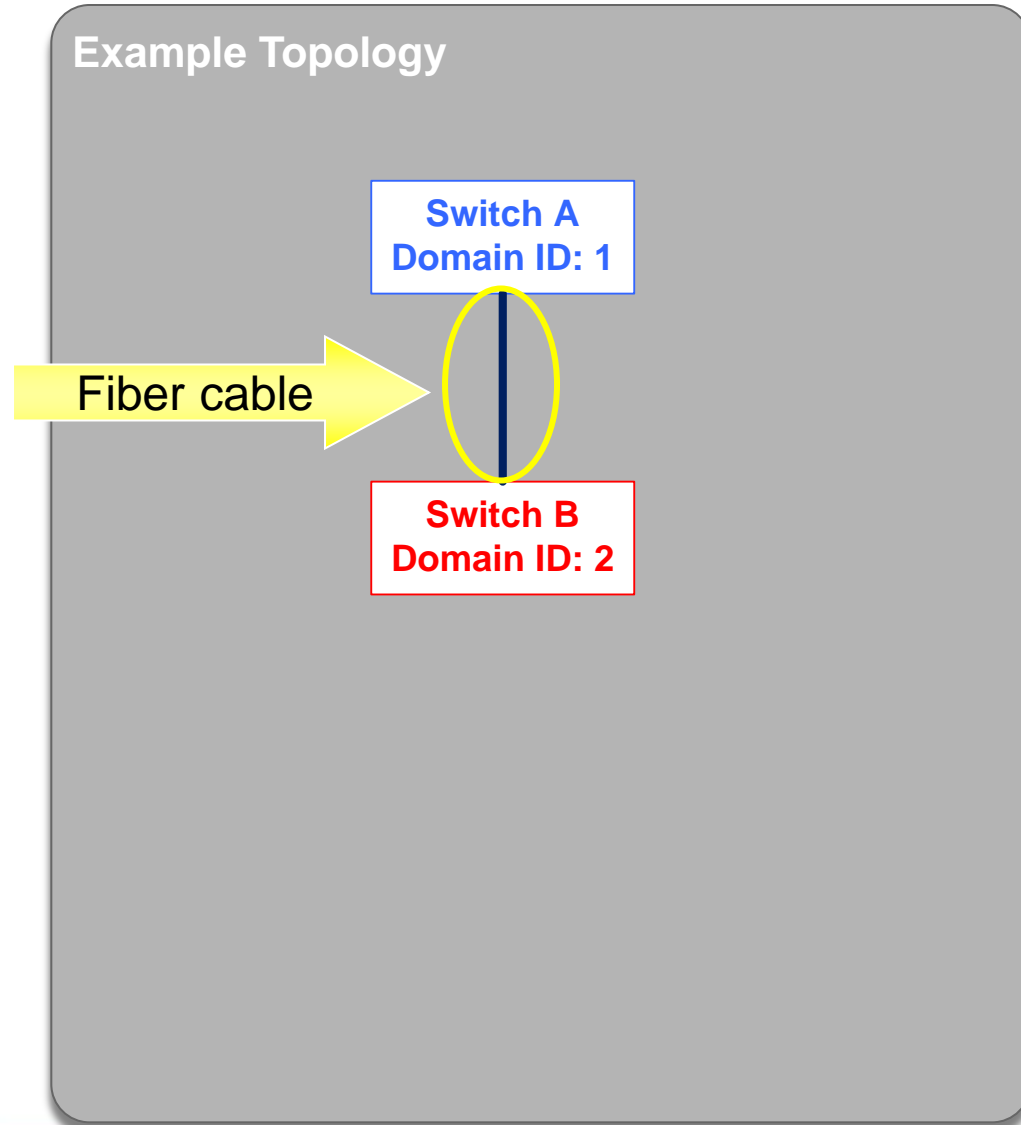
- Very basic flow for the Build Fabric process and how Buffer Credits get initialized



Build Fabric Process

Assume

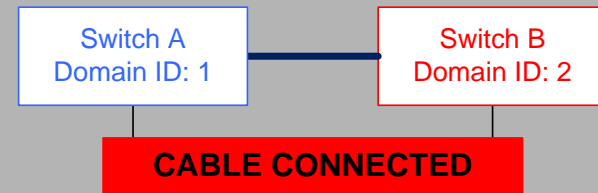
- A fiber cable will be attached between switch A and B
- This will create an ISL (E_Port) between these two devices



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 Params (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

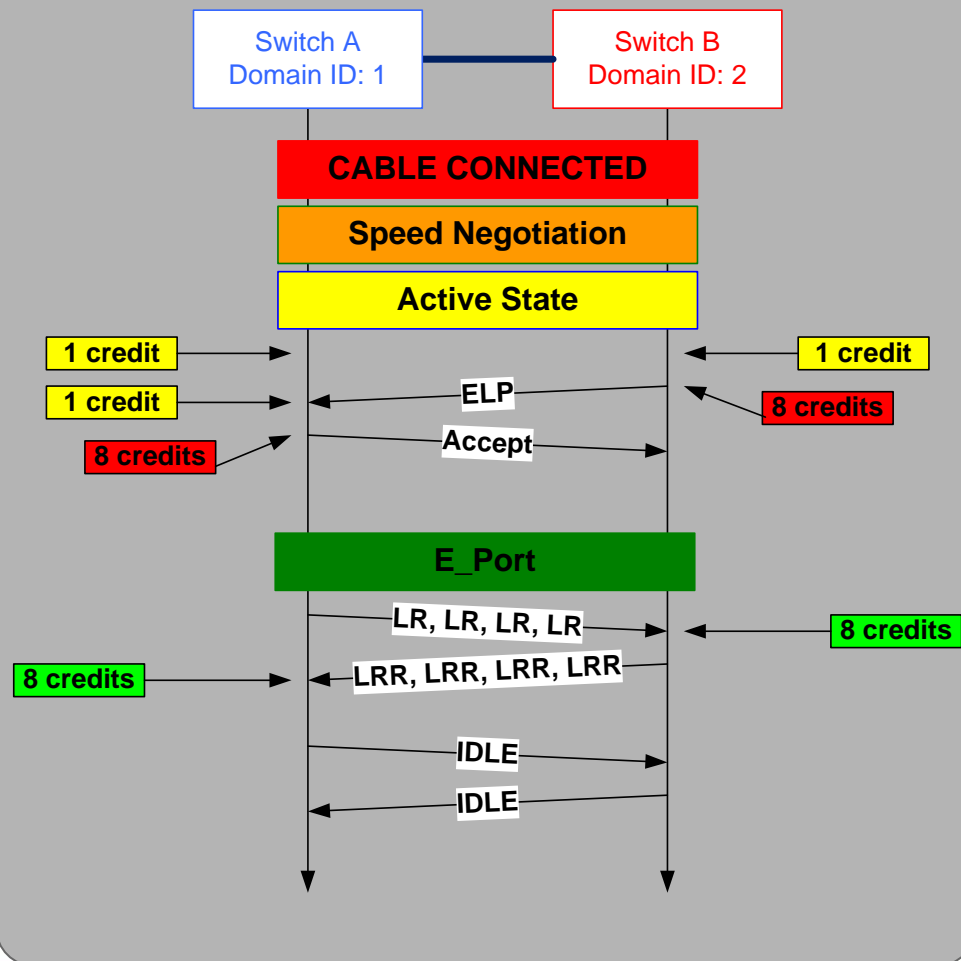
Link Initialization



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 Params (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**

Link Initialization



This Section

- How FICON uses Buffer-to-Buffer Credits
- Howard Johnson, BCAF and a Brocade FICON Engineer, presented an excellent session entitled, “Buffer-to-Buffer Credits, Exchanges, and Urban Legends” yesterday at 1:30pm
- I hope you got an opportunity to hear it



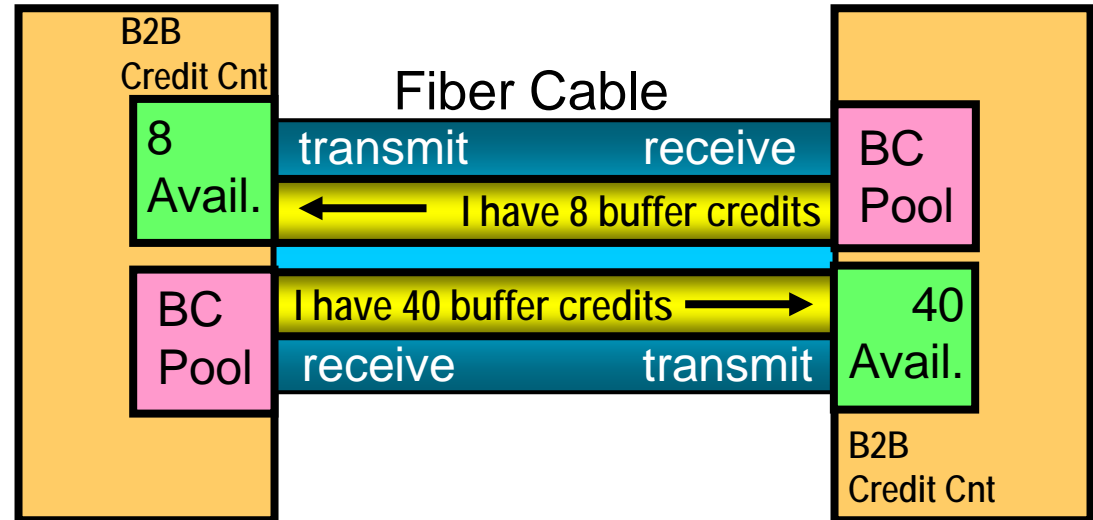
How Buffer Credits Work



- 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

System z
FICON X8/8S
CHPID

Brocade
Dir. Port



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

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

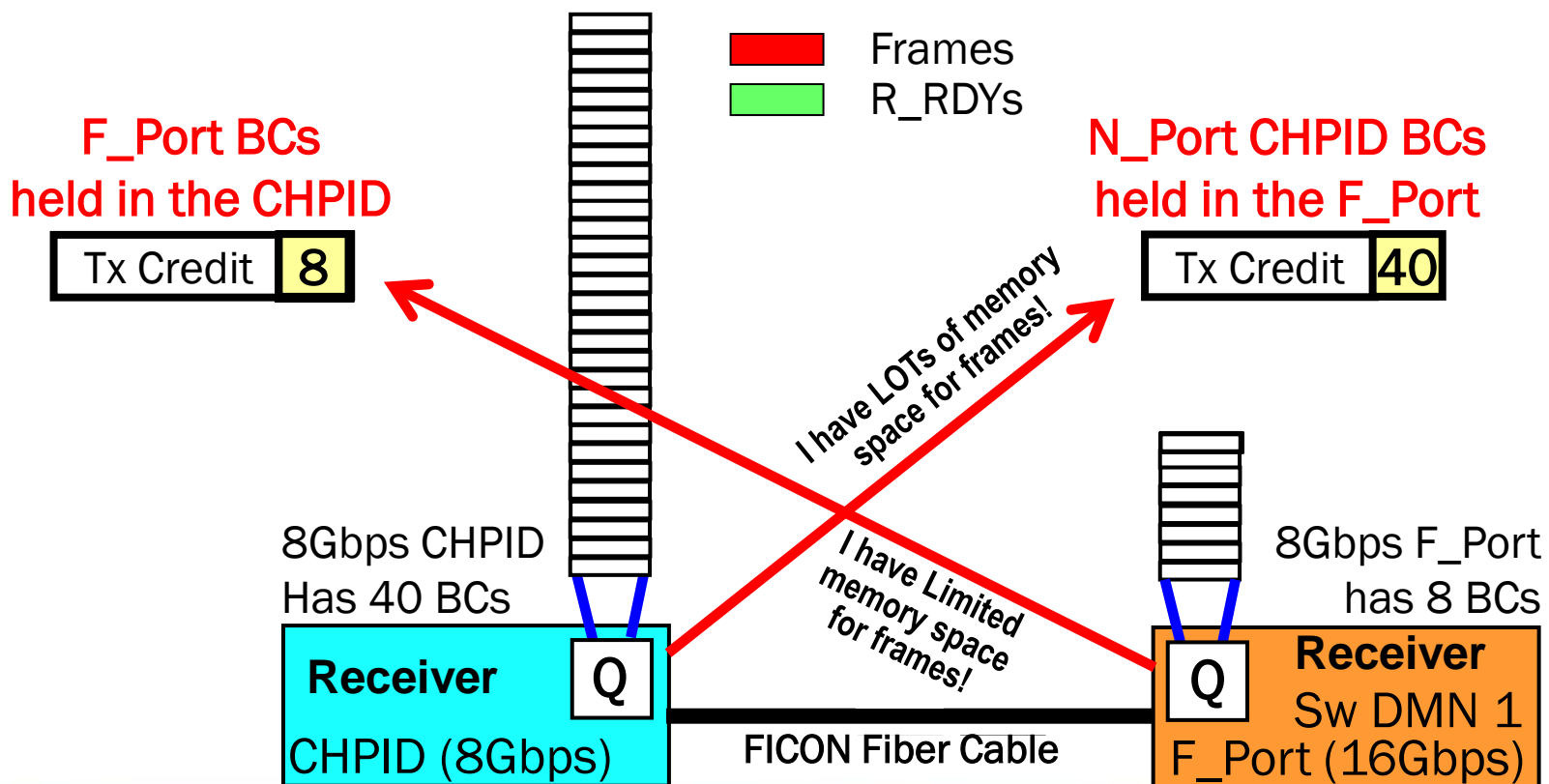
Each receiver on the fiber cable can state a different value!

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

Buffer-to-Buffer Credits

Buffer-to-Buffer flow control

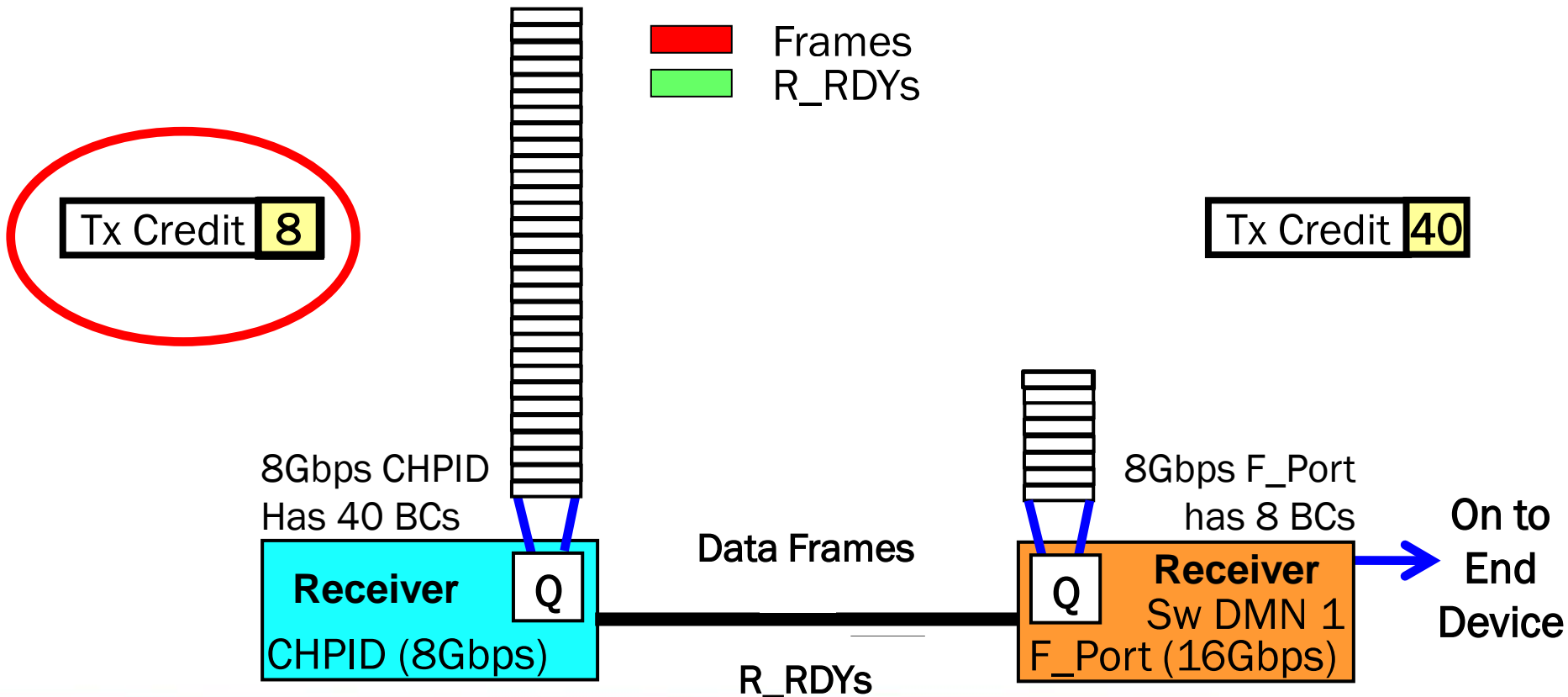
- After initialization, each port knows how many buffers are available in the queue **at the other end of the link**
 - This value is known as Transmit (Tx) Credit



Buffer-to-Buffer Credits

Buffer-to-Buffer flow control Example

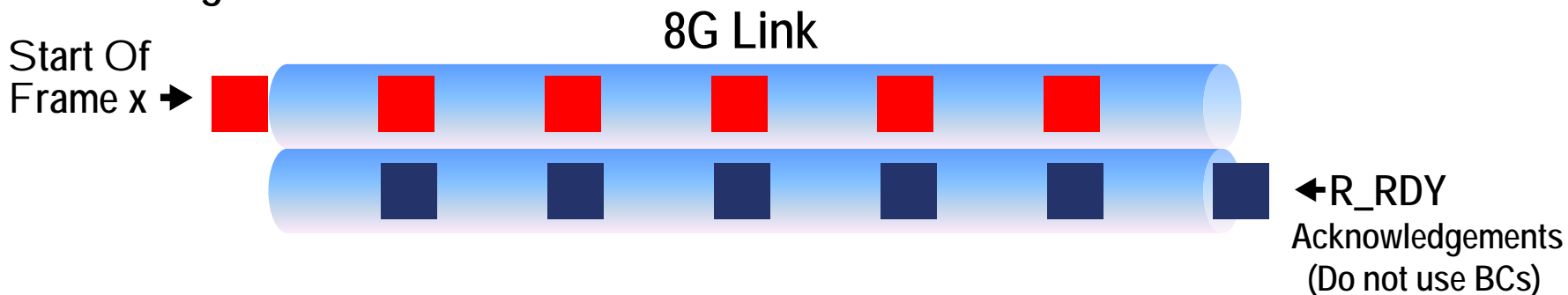
- Tx Credit is **decremented** by one for every frame sent from the CHPID
- No frames may be transmitted after Tx Credit reaches zero
- Tx Credit is **incremented** by one for each R_RDY received from F_Port



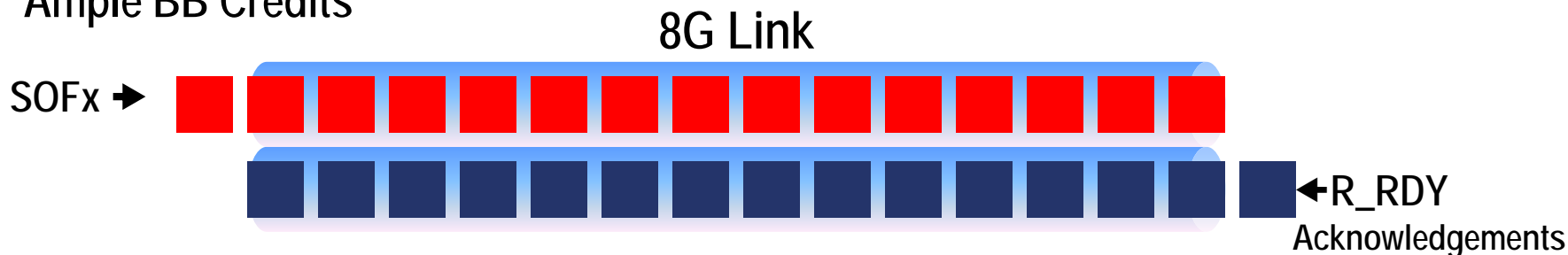
BB Credit Droop



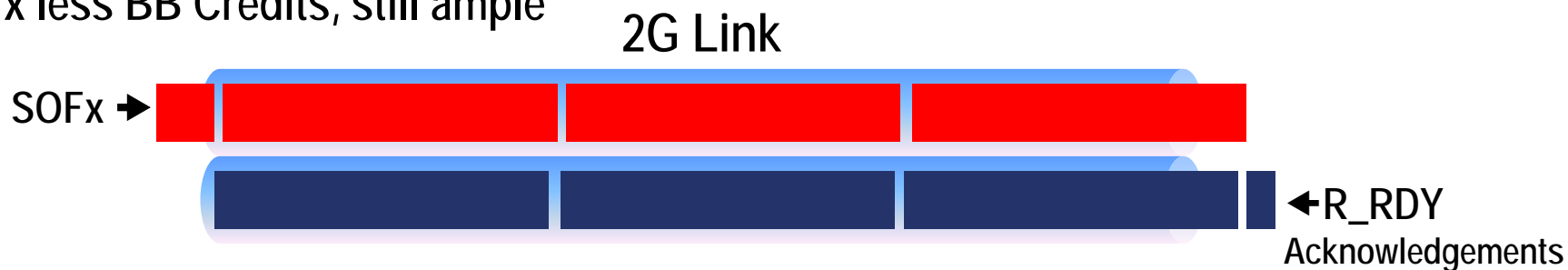
Not Enough BB Credits



Ample BB Credits



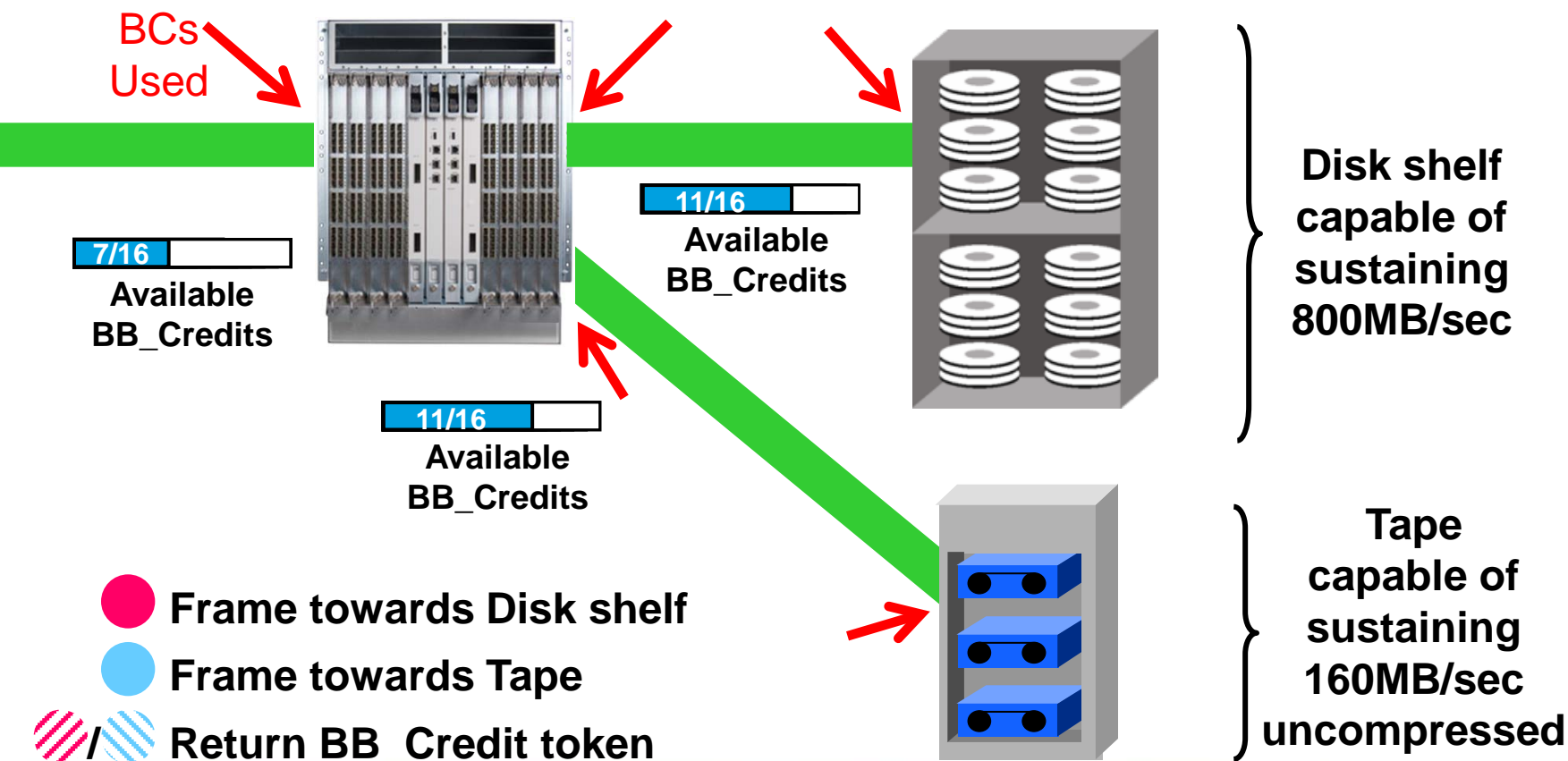
4 x less BB Credits, still ample



Buffer Credits Working Ideally

Buffer Credits are a “Flow Control” mechanism to assure that frames are sent correctly (engineers call this “Frame Pacing”)

In an ideal FC network all devices can process frames at the same rate and negotiate equal levels of BB_Credits)



This Section

- ISL Oversubscription

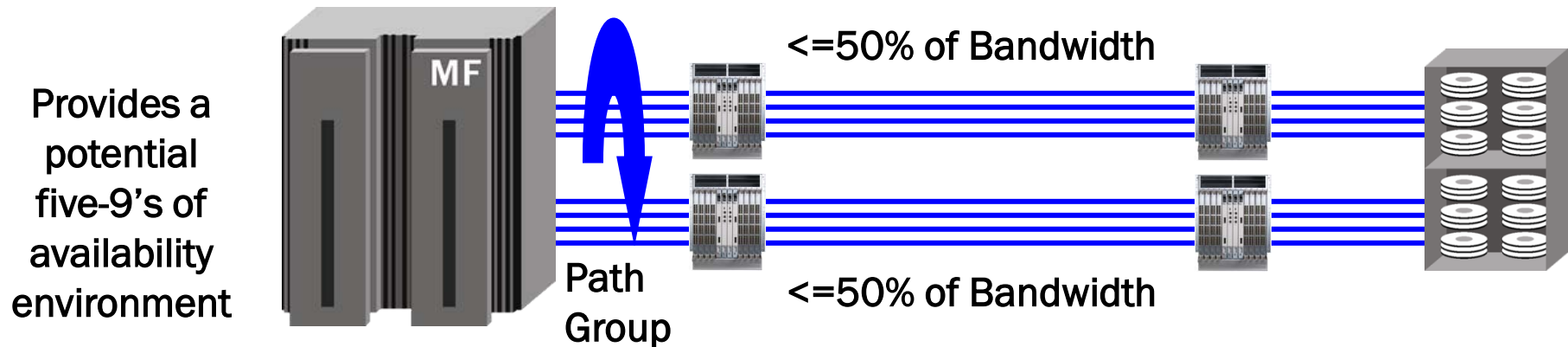
NOTE:

There is also fabric oversubscription and link oversubscription.

In this session I think that **ISL Oversubscription** will demonstrate how serious a concern that oversubscription really can be to the enterprise.



ISL Oversubscription – Design Architecture



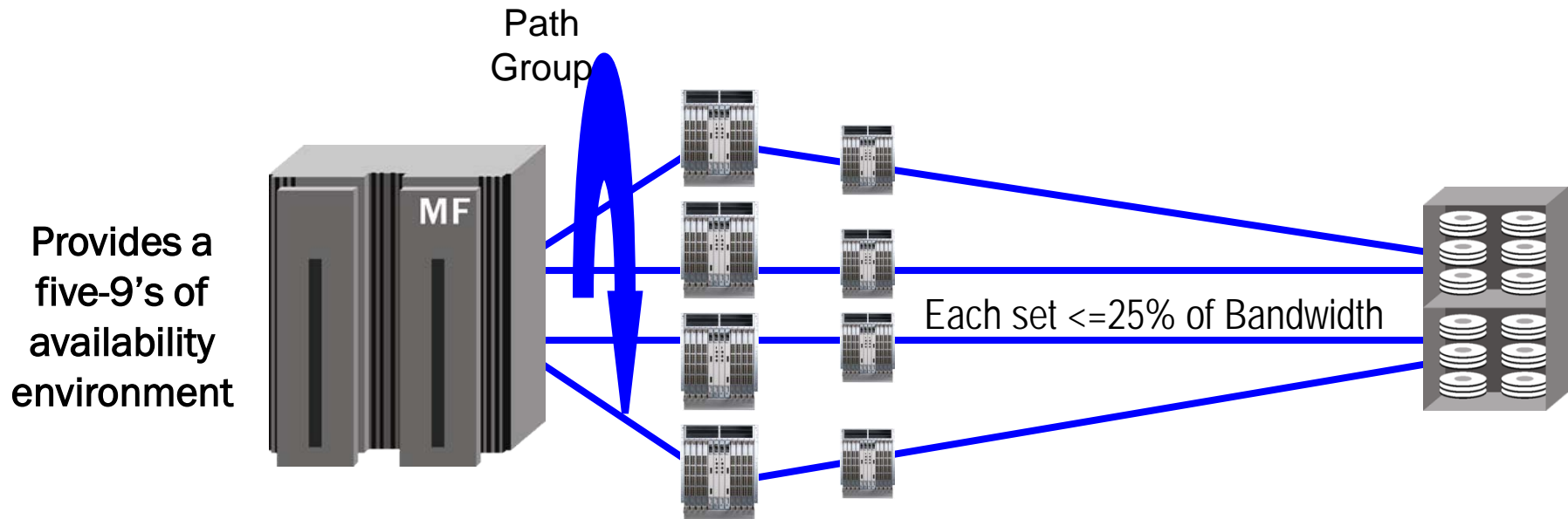
But each fabric really needs to run at no more than 45% busy so that if a failover occurs then the remaining fabric can pickup and handle the full workload

z/OS's IOS automatically load balances the FICON I/O across all of the paths in a Path Group (up to 8 channels in a PG)

- Although this *potentially* provides a five-9s environment, when a fabric does fail how devastating will it be to you in the event that another event occurs and the remaining fabric also fails ?
- Especially when humans get involved, multiple failures too often do occur!

ISL Oversubscription – Design Architecture

Having 4 fabrics servicing a Path Group protects your enterprise's I/O availability!



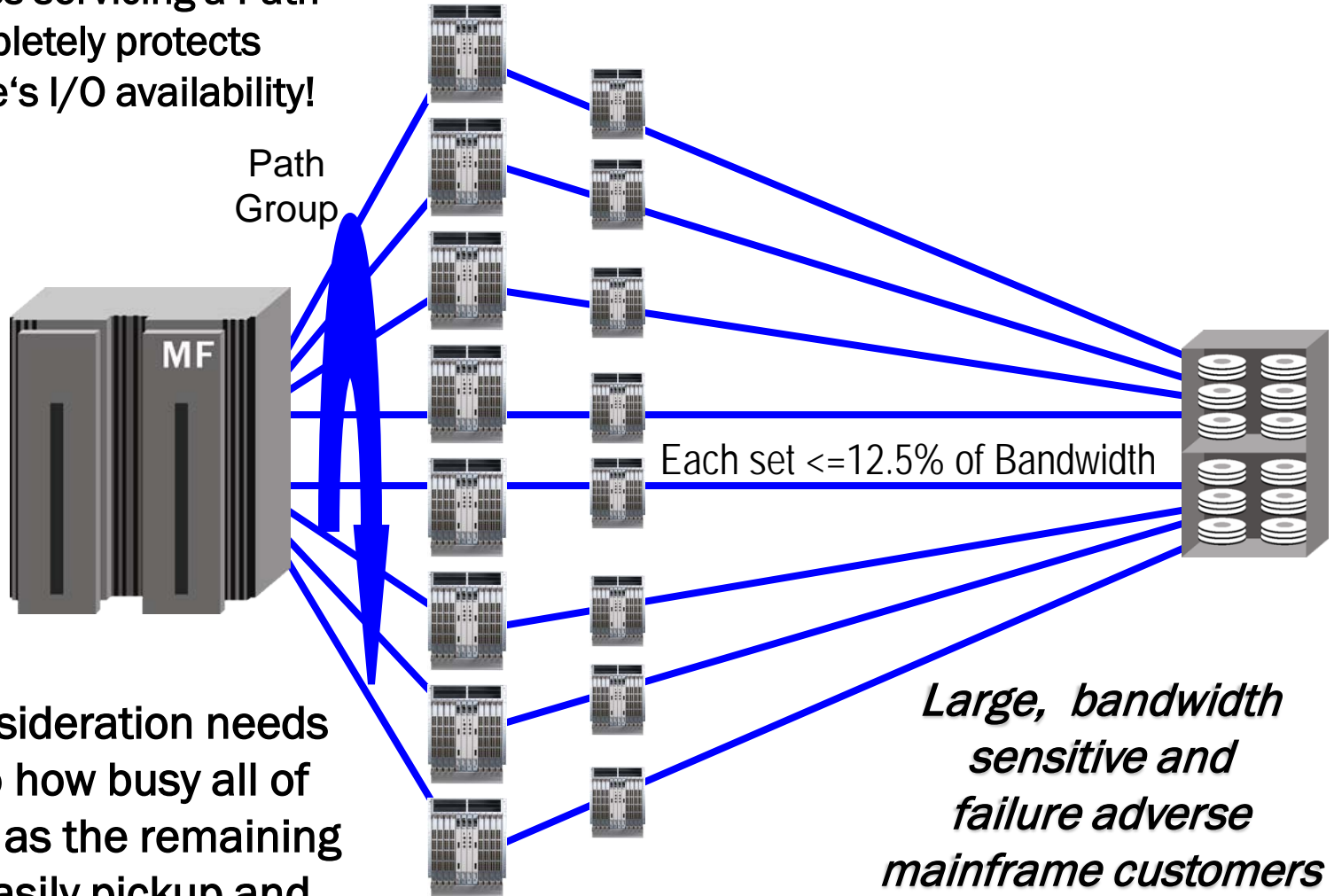
A little consideration needs to be given to how busy all of the fabrics are but the remaining fabrics should easily pickup and handle the full workload

ISL Oversubscription – Design Architecture



Having 8 fabrics servicing a Path Group completely protects your enterprise's I/O availability!

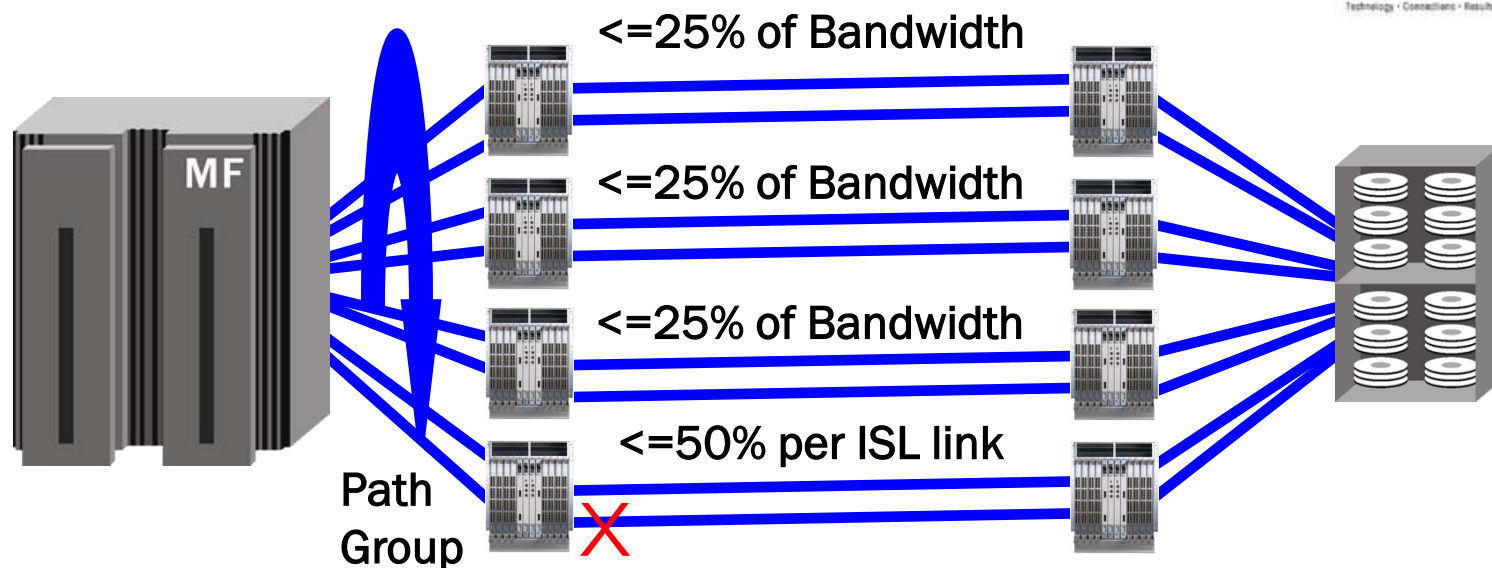
Provides a five-9's of availability environment



Not much consideration needs to be given to how busy all of the fabrics are as the remaining fabrics can easily pickup and handle the full workload

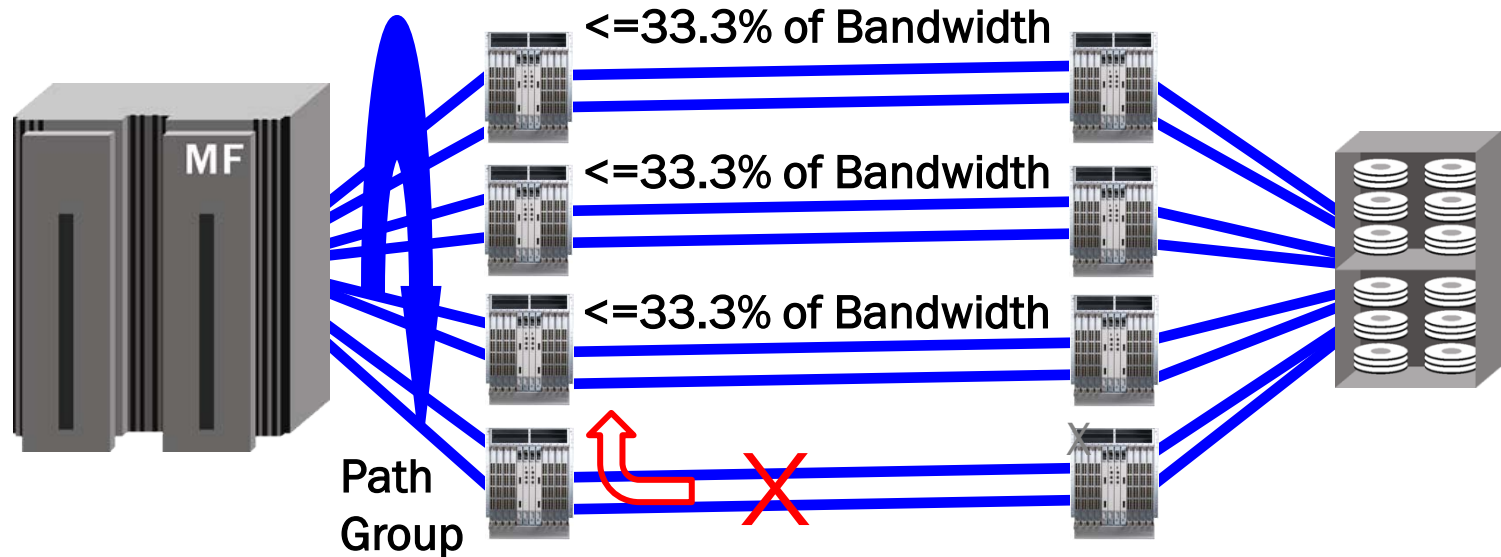
Large, bandwidth sensitive and failure adverse mainframe customers might benefit from configurations like this!

ISL Oversubscription – Design Architecture



- Risk of Loss of Bandwidth is the motivator for deploying FICON fabrics like this
- In this case, 2 paths from an 8 path Path Group are deployed across four FICON fabrics to limit bandwidth loss to no more than 25% if a FICON fabric were to fail
- Each fabric needs to run at no more than ~50-60% busy so that if a failover occurs then the remaining fabrics can pickup and handle the full workload without over-utilization and with some extra utilization to spare per fabric
- If an ISL link in a single fabric fails then that fabric runs at only 50% capability

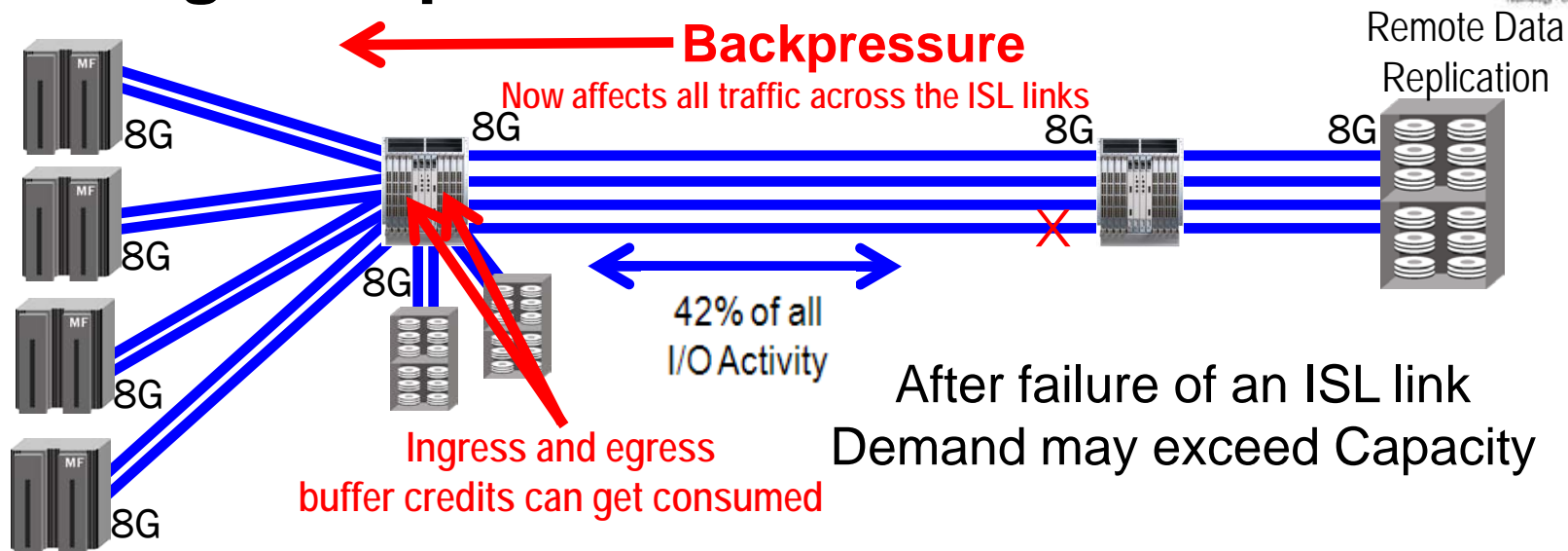
ISL Oversubscription – After a Failure Demand may exceed capacity



- In this case if a switching device fails ...or... if the long distance links in a fabric fails then the frame traffic that was traveling across the now broken links will be rerouted through the other fabrics to reach the storage device
- Those remaining fabrics must have enough reserve capacity in order to pick up all of the rerouted traffic while maintaining performance
- Congestion and potential back pressure could occur if all fabrics are running at high utilization levels – again, probably above 50% or 60% utilization
- **Customers should manage their fabrics to allow for rerouted traffic**

ISL Oversubscription

Creating Backpressure Problems on an ISL



- In This Example:
 - 8G CHPIDs and ISLs are capable of 760MBps send/receive ($800 * .95=760$)
 - Two CHPIDs per mainframe (1520MBps) and 4 mainframes (6080MBps)
 - About 42% of I/O activity is across the ISLs and requires **2550MBps**
 - Four ISLs provides 3040MBps – ($760MBps * 4$) – and a little extra
 - Then one ISL fails leaving only **2280MBps** – ($760MBps * 3$) – not enough redundancy
 - $2280MBps / 2550MBps = 89\%$ of what is required (**Congestion Will Occur**)
 - Each CHPID experiences backpressure as the remaining 3 ISLs become congested and unable to handle all of the I/O traffic

This Section

- Slow Draining Devices



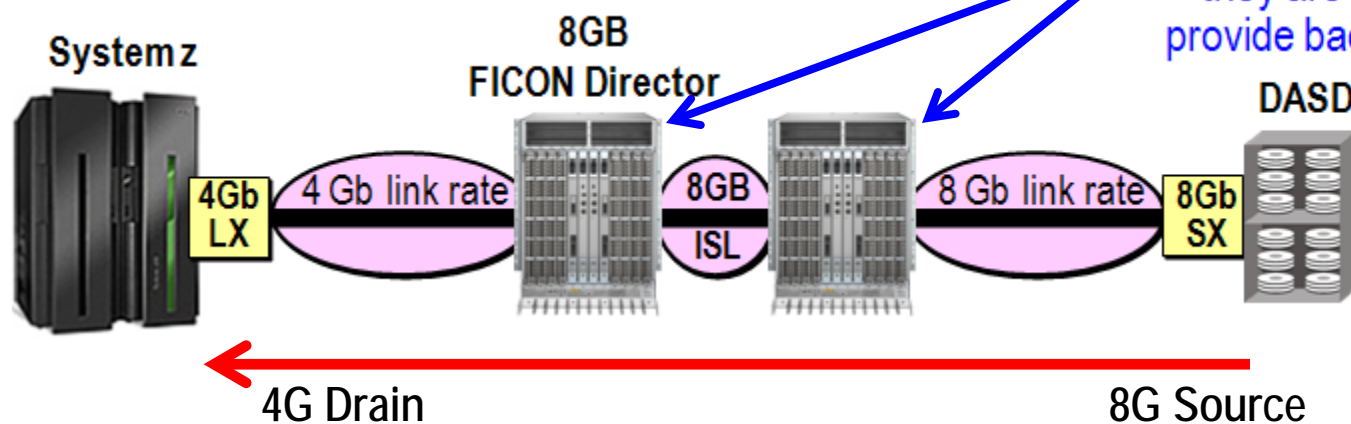
Slow Draining Devices



- 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 than 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 11003)
(Adding 8G DASD with only 4G CHPIDs)



Buffer credits can get used up trying to hold the DASD data while they are waiting on the CHPID to provide back the acknowledgements.

- 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!)

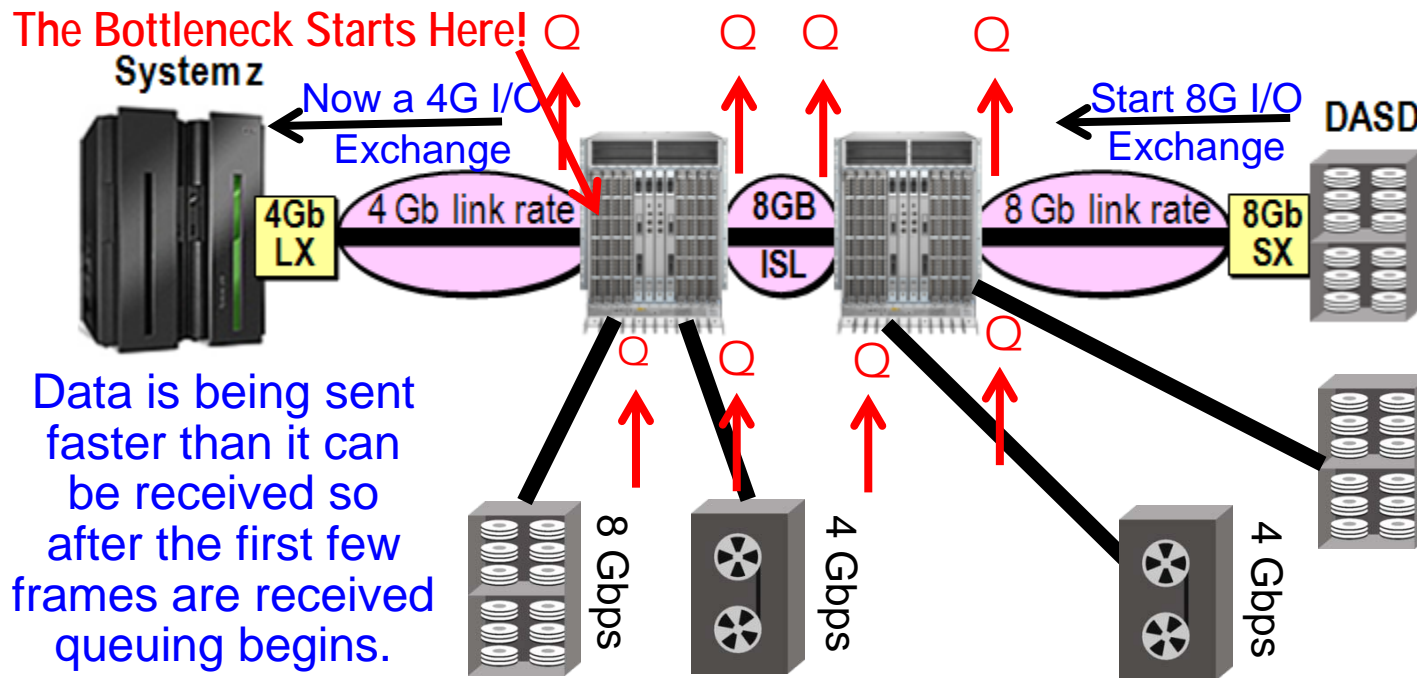


Once an ISL begins ingress port queuing then quite a bit more backpressure can build up in the fabric because of multi-exchange congestion building up on the ISL link(s)



Buffer Credit queuing will create back-pressure on the channel paths.

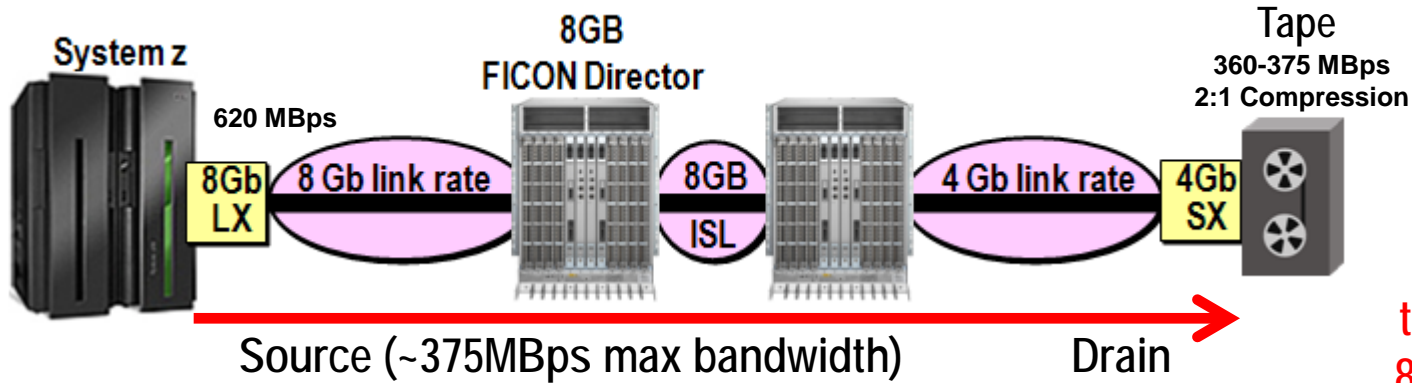
This example assumes that all of the I/O traffic is going to the one CHPID or replication of data is going across the ISL



Data is being sent faster than it can be received so after the first few frames are received queuing begins.

- There 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 $\leq 620\text{MBps}$

- 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 ($400 * .95 = 380\text{MBps}$)
- 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 ($620 / 360 = 1.72$)

This Section

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



Buffer Credits

Why FICON Never Averages a Full Frame Size



- 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	76	Prefix command, etc.
Write	2084 (-64 FICON DB)	2148 72
Status Accept	68	

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 1st frame of every FICON exchange.

$$\text{Average} = (76+2084+2148+72+68) / 5 = 890 \text{ Bytes}$$

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	1968	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?

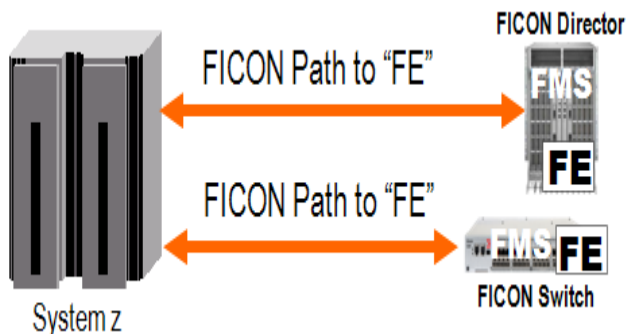


- If a malfunction occurs in the fabric or.....
- If a CHPID or device is having a problem...
- It is certainly possible that some or all of the I/O will time out
- If ANY I/O does time out then:
 - All frames and buffers for that I/O (buffer credits) must be discarded
 - All frames and buffers for subsequently 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



PAGE 1

```

FICON DIRECTOR ACTIVITY
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: 05  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
    
```

- 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

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-		AVG FRAME PACING	AVG FRAME SIZE		PORT BANDWIDTH (MB/SEC)		ERROR COUNT
	UNIT	ID		READ	WRITE	-- READ --	-- WRITE --	
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	550	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



We have a BC Calculator that you can use!

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

Link Speed									
Parameter	1 Gbps	2 Gbps	4 Gbps	8 Gbps	10 Gbps	16 Gbps	32 Gbps	40 Gbps	100 Gbps
Velocity of light in fibre	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)	8.05E-06	4.02E-06	2.01E-06	1.01E-06	8.05E-07	5.03E-07	2.51E-07	2.01E-07	8.05E-08
Framelength in km (dependent on cell I19)	1.61	0.80	0.40	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 D15:
(1 mile = 1,609344 kilometer)

15 Miles Equals 24 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 D19)====> 819 Payload bytes and 36 overhead bytes equals a total frame size of 855 Bytes

Type in the total kilometers of the wire run (in cell D20)====> 24 Kilometers
(Use the calculated kilometers from cell F15 if required)

Description	1 Gbps	2 Gbps	4 Gbps	8 Gbps	10 Gbps	16 Gbps	32 Gbps	40 Gbps	100 Gbps
Framelength takes up this many kilometers on the wire (calculated from frame size in cell I19)	1.61	0.80	0.40	0.20	0.16	0.10	0.05	0.04	0.02
Buffercredits @ 100% B/W Utilization raw calculation:	29.83	59.66	119.32	238.64	298.30	477.28	954.56	1193.21	2983.02
Buffercredits @ 100% B/W Utilization rounded up:	30	60	120	239	299	478	955	1194	2984

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

This Section

- Brocade's professionally recognized FICON Certification

**Brocade
Certified Architect
for FICON**



Industry Recognized Professional Certification

» Brocade FICON Certification

Brocade
Certified Architect
for FICON



- Certification for Brocade Mainframe-centric Customers
- Available since September 2008
- Updated for 8Gbps in June 2010
- Slated for 16Gbps update in September 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!***
- Ask me how to make that happen for you!

We Help Our Customer's Capitalize On Our Expertise



» Brocade FICON Certification

Brocade
Certified Architect
for FICON



- Ran Brocade Certified Architect for FICON (BCAF) class 31 times in the past 20 months:
 - USA, EMEA, South America, Asia and Japan
- 389 total students completed the FICON Certification class
- We continue to run these classes during 2012
 - Thailand – done
 - Indonesia – done
 - Italy – done
 - UK – scheduled (April)
 - Spain – scheduled (April)

Other SAN Sessions at SHARE this week



Tuesday:

Time-Session

1800 - 11022: FICON Director and Channel Free-For-All

Visit Brocade's Mainframe Blog Page at:

<http://community.brocade.com/community/brocadeblogs/mainframe>

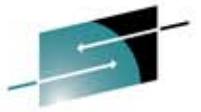
Also Visit Brocade's New Mainframe Communities Page at:

http://community.brocade.com/community/forums/products_and_solutions/mainframe_solutions





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Please Fill Out Your Evaluation Forms!!

This was session: 11004

And Please Indicate On Those Forms If There Are Other Presentations That You Would Like To See In This SAN Track At The Next SHARE.

