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Detecting, Alerting, Identifying and Proactively Preventing SAN Congestion

Getting your SAN to perform at its best

Edward Mazurek, Principal Engineer, CX
@theRealEdMaz

BRKDCN-3641

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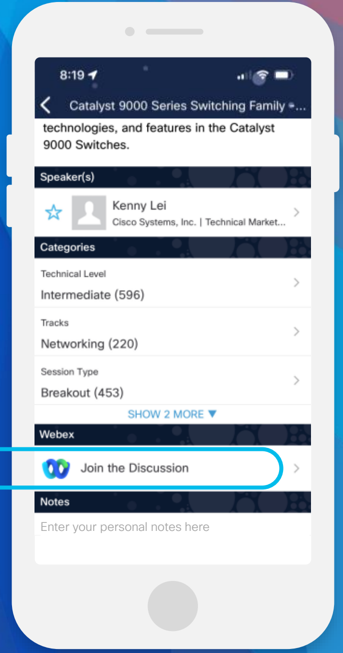

8:19

Catalyst 9000 Series Switching Family •...

technologies, and features in the Catalyst 9000 Switches.

Speaker(s)

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Agenda

- Overview
- Understanding SAN Congestion
- Detecting SAN Congestion
- Troubleshooting SAN Congestion
- Proactively preventing SAN Congestion

Overview

What is this ‘SAN Congestion’ thing?

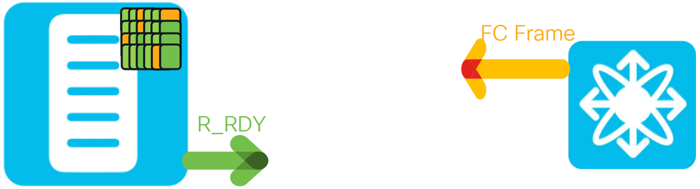
- Why am I referring to ‘SAN Congestion’ instead of ‘Slow Drain’?
- Everyone knows ‘Slow Drain’, so why ‘SAN Congestion’?
- Why should I be concerned?

Understanding SAN Congestion

Understanding SAN Congestion

Fibre Channel Buffer-to-Buffer Flow Control - The Basics

- Fibre Channel is a ‘lossless’ network protocol
- Sender does not send a frame unless the receiver has a buffer
- ‘Fibre Channel utilizes Buffer-to-Buffer(B2B) Credit based flow control
- Each side of link informs adjacent side of the number of buffers/credits
- Each frame sent requires a B2B credit to be returned
- B2B credits are also called ‘R_RDYs’
- Frame receivers can slow rate of ingress traffic by ‘withholding’ credits
- If a sender runs out of credits it must stop sending until it receives one



Understanding SAN Congestion

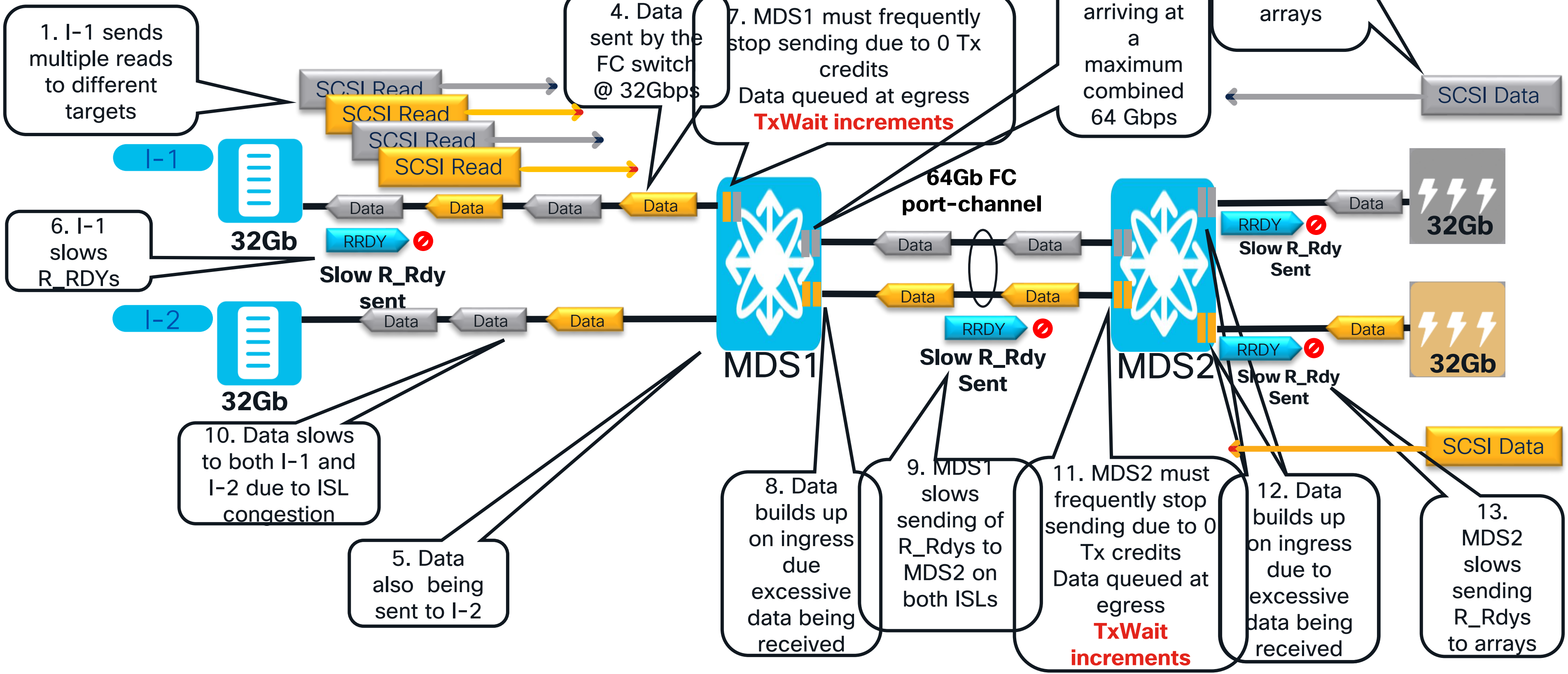
There are 4 reasons for congestion in a Fibre Channel SAN

1. Slow Drain – Receiver purposely slowing down traffic by withholding R_RDYs
2. Over-Utilization – Receiver requesting more data than can be transmitted
3. Insufficient B2B credits for the link's distance(latency), speed and frame size
4. B2B credits lost due to bit errors or Invalid Transmission Words(ITW)

#1, #2 and #4 are the focus of this presentation

Slow Drain - Example

“Typical” Slow Drain causing ISL and array congestion



1. I-1 sends multiple reads to different targets

2. Data sent by both arrays

3. Data arriving at a maximum combined 64 Gbps

4. Data sent by the FC switch @ 32Gbps

5. Data also being sent to I-2

6. I-1 slows R_RDYs

7. MDS1 must frequently stop sending due to 0 Tx credits
Data queued at egress
TxWait increments

8. Data builds up on ingress due excessive data being received

9. MDS1 slows sending of R_Rdys to MDS2 on both ISLs

10. Data slows to both I-1 and I-2 due to ISL congestion

11. MDS2 must frequently stop sending due to 0 Tx credits
Data queued at egress
TxWait increments

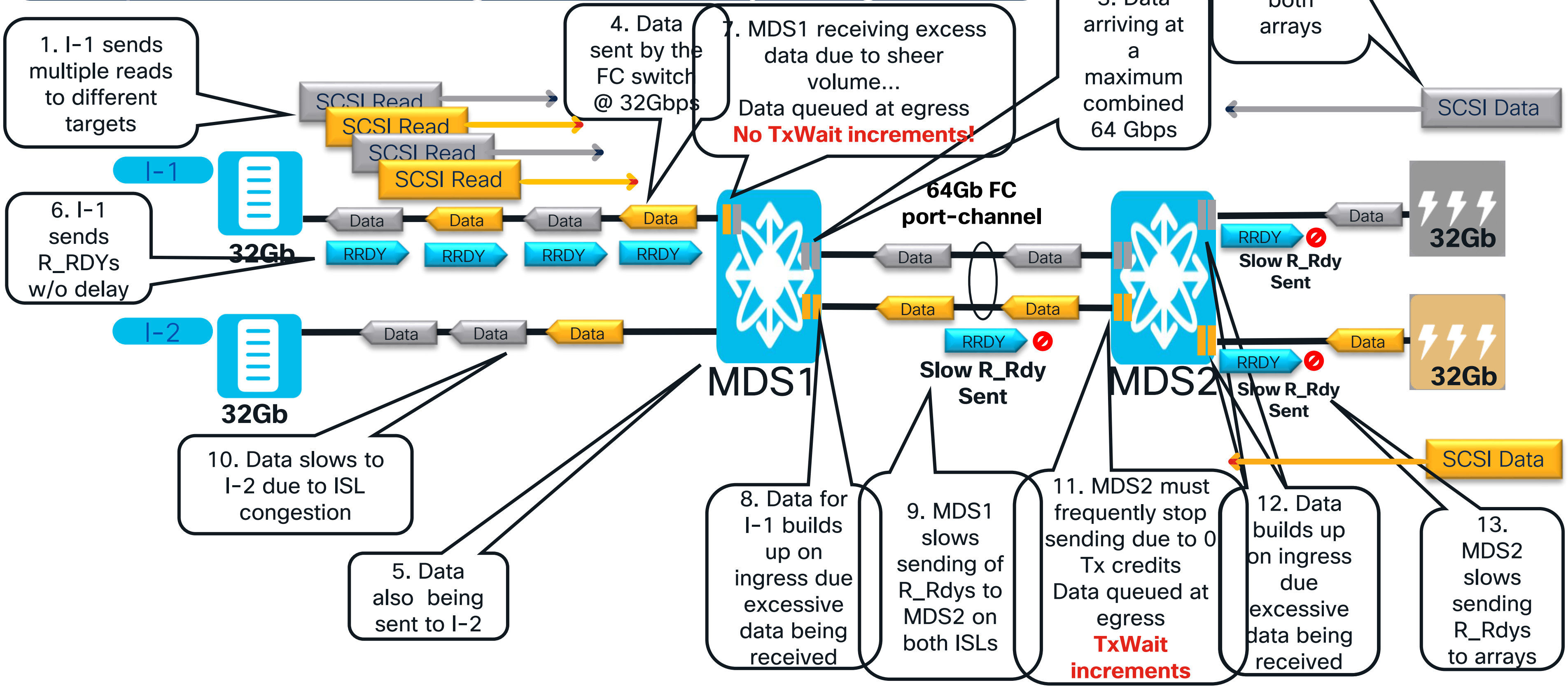
12. Data builds up on ingress due to excessive data being received

13. MDS2 slows sending R_Rdys to arrays

Both arrays and all devices utilizing ISLs are affected!

Over-Utilization - Example

Multiple Reads causing ISL and array congestion



1. I-1 sends multiple reads to different targets

2. Data sent by both arrays

3. Data arriving at a maximum combined 64 Gbps

4. Data sent by the FC switch @ 32Gbps

5. Data also being sent to I-2

6. I-1 sends R_RDYs w/o delay

7. MDS1 receiving excess data due to sheer volume…
Data queued at egress
No TxWait increments!

8. Data for I-1 builds up on ingress due excessive data being received

9. MDS1 slows sending of R_Rdys to MDS2 on both ISLs

10. Data slows to I-2 due to ISL congestion

11. MDS2 must frequently stop sending due to 0 Tx credits
Data queued at egress
TxWait increments

12. Data builds up on ingress due excessive data being received

13. MDS2 slows sending R_Rdys to arrays

Not strictly “slow drain” but the effects are exactly the same!

Comparison of Slow Drain vs. Over-Utilization

Slow Drain

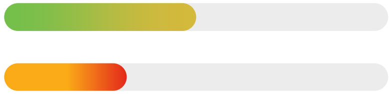
Tx B2B credit starvation

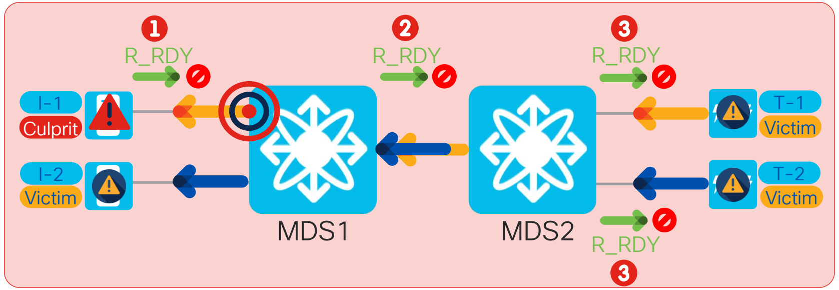
I-1 is busy

I-1 slows down its ingress traffic rate by slowing down sending of R_RDY to MDS1

Tx Utilization % (tx-datarate)

Tx Congestion % (txwait)





Over-utilization

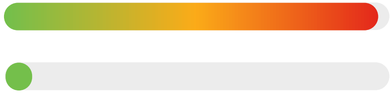
Receive data rate on ISL port is faster than the host port speed

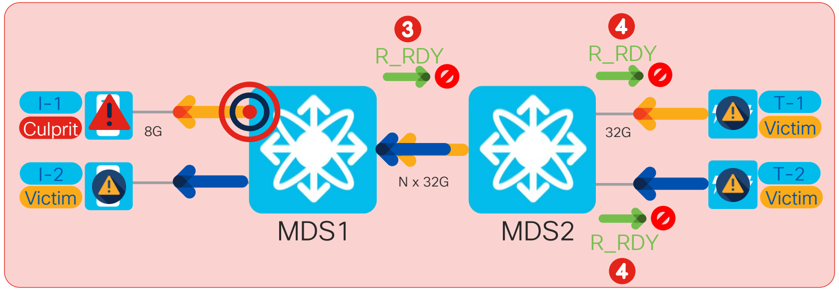
I-1 is receiving at full capacity

MDS1 slows down traffic rate to I-1 by slowing down sending of R_RDY to MDS2

Tx Utilization % (tx-datarate)

Tx Congestion % (txwait)





Frames are not dropped in FC fabric. Rather, they consume switch buffers causing a fabric-wide congestion spreading

Detecting SAN Congestion

Understanding TxWait

- TxWait is the basic metric for determining/quantifying **Slow Drain**
- TxWait is an ASIC counter that increments by 1 as a port is unable to transmit a queued frame for 2.5 microseconds due to Tx B2B credit unavailability

```
mds9710# show interface fc1/1 counters | include ignore-case wait
 26009409536 2.5us TxWait due to lack of transmit credits
 Percentage TxWait for last 1s/1m/1h/72h: 0%/50%/22%/6%
```

- Convert TxWait to seconds by (TxWait * 2.5) / 1000000
  - In the above output, **26009409536** * 2.5/1000000 = 65,023 seconds
  - MDS was not able to transmit for 65,023 seconds since the counter was last cleared
- MDS enriches the raw TxWait counter:
  - For storing on switch OBFL (On-board Failure Logging (Buffer)) for troubleshooting
  - TxWait History graphs
  - For automated alerting and actions by port-monitor (PMon)
  - Export via SNMP or NX-API to remote systems like NDFC/DCNM slow drain analysis

TxWait OBFL on MDS

- TxWait delta value is logged periodically(20 seconds) into OBFL, if delta value >=100ms.
- Displays TxWait time in 2.5µs ticks as well as in seconds.
- Timestamp of event occurrence also recorded.

```
MDS9706-C# show logging onboard txwait
---------------------------------
Module: 10 txwait
---------------------------------
Notes:
     - Sampling period is 20 seconds
     - Only txwait delta >= 100 ms are logged

---------------------------------------------------------------------------------------------
| Interface | Virtual Link | Delta TxWait Time        | Congestion | Timestamp                |
|           |              | 2.5us ticks | seconds    |            |                          |
---------------------------------------------------------------------------------------------
|   fc1/15  | None         |     86510   |     0      |         1% | Thu Feb 10 15:11:42 2022 |
|   fc1/15  | None         |     46459   |     0      |         0% | Thu Feb 10 15:11:22 2022 |
|   fc1/15  | None         |   1129160   |     2      |        14% | Sat Oct 16 00:09:52 2021 |
|   fc1/15  | None         |    658894   |     1      |         8% | Tue Oct 12 02:18:50 2021 |
```

Logged individually per module

Congestion **percentage** is calculated over the 20 second interval

Understanding Tx-datarate – Port Utilization

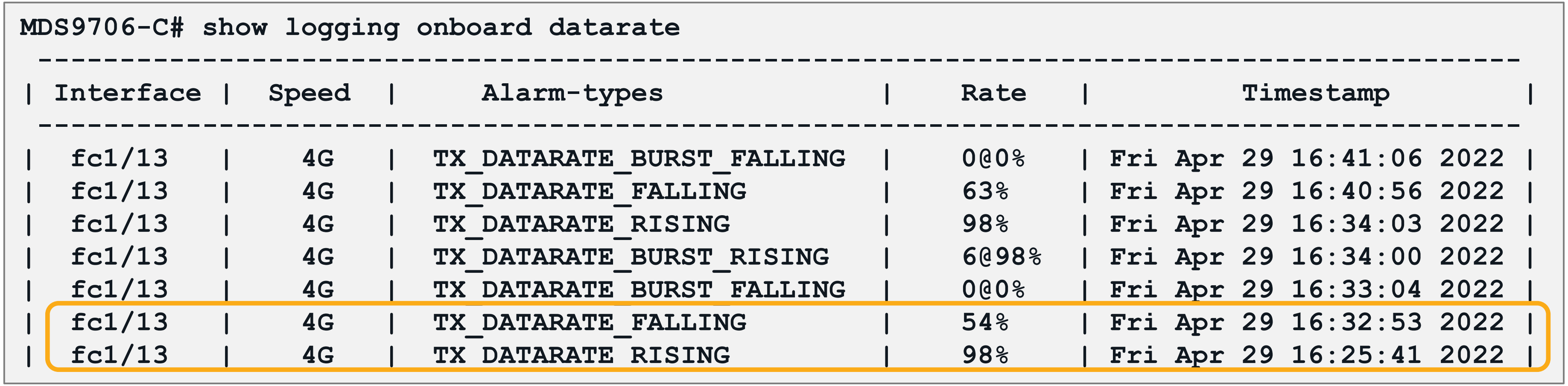
- Tx-Datarate is the basic metric for determining **Over-Utilization**
- Port-monitor on MDS measures datarate in percent utilization.
- Two available methods:
  - Tx-datarate: tx utilization >= 80% (*) continuously for 10 seconds (*)
  - Tx-datarate-burst: 5 (*) times in 10 seconds (*) tx utilization > 90% (*) continuously for 1 second
- An event is recorded when the high threshold(rising-threshold) is reached
- An event is recorded when the low threshold(falling-threshold is reached
- The interface was highly utilized for the time between those events

For all practical purposes, due to longer polling intervals in production environments, treat any occurrence of high utilization the same as over-utilization, which may cause congestion

(*) = user configurable

Tx-datarate OBFL in MDS

- High-utilization events are stored in the switch



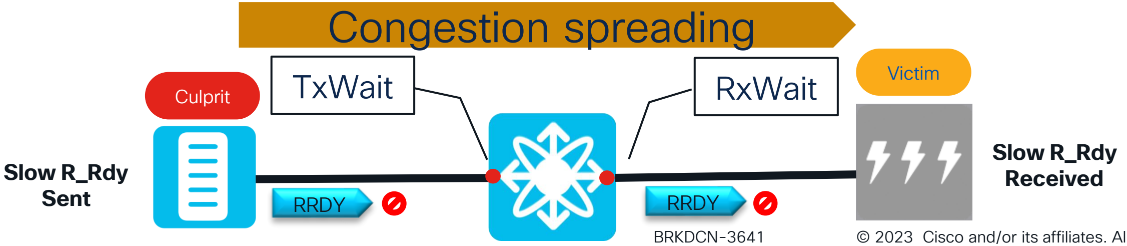
```
MDS9706-C# show logging onboard datarate
 ---------------------------------------------------------------------------
| Interface |  Speed  |     Alarm-types              |    Rate    |         Timestamp          |
 ---------------------------------------------------------------------------
|  fc1/13   |    4G   |  TX_DATARATE_BURST_FALLING  |    0@0%    | Fri Apr 29 16:41:06 2022 |
|  fc1/13   |    4G   |  TX_DATARATE_FALLING        |    63%     | Fri Apr 29 16:40:56 2022 |
|  fc1/13   |    4G   |  TX_DATARATE_RISING         |    98%     | Fri Apr 29 16:34:03 2022 |
|  fc1/13   |    4G   |  TX_DATARATE_BURST_RISING   |    6@98%   | Fri Apr 29 16:34:00 2022 |
|  fc1/13   |    4G   |  TX_DATARATE_BURST_FALLING  |    0@0%    | Fri Apr 29 16:33:04 2022 |
|  fc1/13   |    4G   |  TX_DATARATE_FALLING        |    54%     | Fri Apr 29 16:32:53 2022 |
|  fc1/13   |    4G   |  TX_DATARATE_RISING         |    98%     | Fri Apr 29 16:25:41 2022 |
```

TX_DATARATE_RISING it started at 10 seconds prior to when it was recorded 16:25:31and ended 10 seconds prior to when the TX_DATARATE_FALLING was recorded 16:32:43. There was high utilization for 7 min 12 seconds.

Port-monitor tx-datarate *must* be configured to log to OBFL!

Introducing... RxWait!

- RxWait is the basic metric for determining ingress congestion
- RxWait is ***new*** in 64G modules and switches starting in NX-OS 9.3(2)
- RxWait measures the amount of time the switchport is preventing ingress frames
- When a switch is experiencing Tx congestion it withholds B2B credits on ports sending to the Tx congested port causing ingress congestion
- RxWait is an ASIC counter that increments by 1 as a port is at 0 Rx B2B credits for 2.5µs
- RxWait indicates ports affected by congestion not those causing congestion
- Previous generations used a software derived counter indicating 100ms of zero Rx credits
- Convert RxWait to seconds by (RxWait * 2.5) / 1000000 (just like TxWait)



Introducing RxWait

```
MDS9710# show interface fc10/1 counters detailed
fc10/1
…
 Congestion Stats:
  Tx Timeout discards:                                                       0
  Tx Credit loss:                                                            0
  TxWait 2.5us due to lack of transmit credits:                              0
  Percentage TxWait for last 1s/1m/1h/72h:                         0%/0%/0%/0%
  RxWait 2.5us due to lack of receive credits:                           12345
  Percentage RxWait for last 1s/1m/1h/72h:                         0%/0%/0%/0%
  Rx B2B credit remaining:                                                1000
  Tx B2B credit remaining:                                                1000
  Tx Low Priority B2B credit remaining:                                   1000
  Rx B2B credit transitions to zero:                                         2
  Tx B2B credit transitions to zero:                                         3
```

- In the above output, 12345 * 2.5/1000000 = 0.0308625 seconds
  - MDS was not able to receive for 0.0308625 seconds since the counter was last cleared
- MDS enriches the raw RxWait counter:
  - Graphical display – **show interface rxwait-history**
  - Last 1 second, 1 minute, 1 hour, 72 hours – **show interface <counters detailed>**
  - Historical logging every 20 seconds in OBFL(On-board Failure Logging) – **show logging onboard rxwait**

RxWait OBFL on MDS

- RxWait delta value is logged periodically(20 seconds) into OBFL, if delta value >=100ms.
- Displays RxWait time in 2.5µs ticks as well as in seconds.
- Timestamp of event occurrence also recorded.

Logged individually per module

Ingress Congestion **percentage** is calculated over the 20 second interval

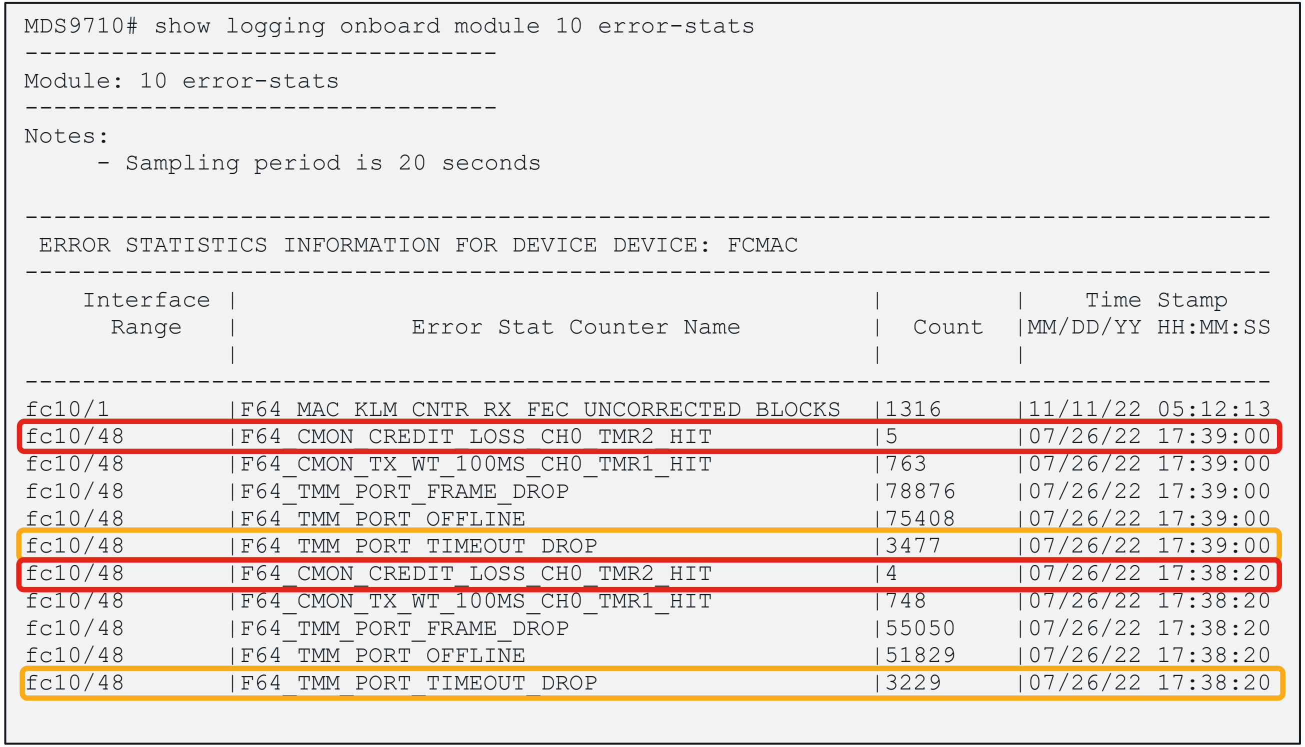
```
MDS9710# show logging onboard rxwait module 10
---------------------------------
Module: 10 rxwait
---------------------------------
Notes:
     - Sampling period is 20 seconds
     - Only rxwait delta >= 100 ms are logged

---------------------------------------------------------------------------------------------
| Interface | Virtual Link | Delta RxWait Time        | Congestion | Timestamp                  |
|           |              | 2.5us ticks | seconds    | (Ingress)  |                            |
---------------------------------------------------------------------------------------------
|   fc10/1  | None         |  6242188    |    15      |       78%  | Thu Jan 12 13:44:34 2023 |
|   fc10/1  | None         |  6211282    |    15      |       77%  | Thu Jan 12 13:44:14 2023 |
|   fc10/1  | None         |  6240818    |    15      |       78%  | Thu Jan 12 13:43:54 2023 |
|   fc10/1  | None         |  6229296    |    15      |       77%  | Thu Jan 12 13:43:34 2023 |
```

Other Congestion Indications

- `Timeout-drops` - Frames dropped due to age in the switch
  - Each frame is time stamped when received on an interface
  - If age of frame exceeds 500ms(default) when it reaches egress interface it is dropped
  - Dropped frames(for any reason) cause IO errors, aborted IOs, application errors
- `Credit-Loss-Recovery` - 1/1.5 seconds of zero Tx credits
  - Occurs when an interface is at zero Tx B2B credits continuously for 1/1.5 seconds
    - 1 second for F/NP ports and 1.5 seconds for E (ISL) ports
  - Link Reset protocol is performed resulting in recovery of credits
  - Most severe indication of congestion in a Fibre Channel SAN
  - Can be caused by bit errors or severe congestion

OBFL error-stats



```
MDS9710# show logging onboard module 10 error-stats
---------------------------------
Module: 10 error-stats
---------------------------------
Notes:
     - Sampling period is 20 seconds

--------------------------------------------------------------------------------------
 ERROR STATISTICS INFORMATION FOR DEVICE DEVICE: FCMAC
--------------------------------------------------------------------------------------
    Interface |                                            |         |    Time Stamp
      Range   |             Error Stat Counter Name        |  Count  |MM/DD/YY HH:MM:SS
              |                                            |         |
--------------------------------------------------------------------------------------
fc10/1        |F64_MAC_KLM_CNTR_RX_FEC_UNCORRECTED_BLOCKS  |1316     |11/11/22 05:12:13
fc10/48       |F64_CMON_CREDIT_LOSS_CH0_TMR2_HIT           |5        |07/26/22 17:39:00
fc10/48       |F64_CMON_TX_WT_100MS_CH0_TMR1_HIT           |763      |07/26/22 17:39:00
fc10/48       |F64_TMM_PORT_FRAME_DROP                     |78876    |07/26/22 17:39:00
fc10/48       |F64_TMM_PORT_OFFLINE                        |75408    |07/26/22 17:39:00
fc10/48       |F64_TMM_PORT_TIMEOUT_DROP                   |3477     |07/26/22 17:39:00
fc10/48       |F64_CMON_CREDIT_LOSS_CH0_TMR2_HIT           |4        |07/26/22 17:38:20
fc10/48       |F64_CMON_TX_WT_100MS_CH0_TMR1_HIT           |748      |07/26/22 17:38:20
fc10/48       |F64_TMM_PORT_FRAME_DROP                     |55050    |07/26/22 17:38:20
fc10/48       |F64_TMM_PORT_OFFLINE                        |51829    |07/26/22 17:38:20
fc10/48       |F64_TMM_PORT_TIMEOUT_DROP                   |3229     |07/26/22 17:38:20
```

Delta Credit-Loss

F64_CMON_CREDIT_LOSS_CH0_TMR2_HIT **5 - 4 = 1 credit-loss**

Delta timeout-drops

F64_TMM_PORT_TIMEOUT_DROP

3477 - 3229 = 248 drops

Time intervals

Credit-loss and timeout-drops occurred in 20 second interval ending in 17:39:00

Other counters

error-stats includes many other types of error counters

Count is total – Must subtract from previous to get delta value

Timeout-drop S_ID / D_ID Identification

Identifies specific S_ID/D_ID of dropped frames – Useful when multiple logins

show hardware internal fcmac port x tmm_timeout_stat_buffer

Shows FC frame header info including S_ID, D_ID to identify victims

Module command (either 'attach module x' or 'slot x' prefix)

```
`slot 1 show hardware internal fcmac port 79 tmm_timeout_stat_buffer`
+-----------------------------------------------------------------------+
| PORT:78 ASIC PORT: 5 PG:1 PG PORT:1 START: 4 END: 7 WR:4 RD:0 NUM PKTS:4 |
+------+--------+--------+---+----+------+------+----+----+----+----+-+----+
|Delay |  Chip  |Vegashdr|TS | FC | Src  | Dest |RCTL| CTL| SI | DI |A|OFF |
|(msec)|time(0x)|time(0x)|VLD|TYPE|  ID  | ID   |(0x)|(0x)|(0x)|(0x)|T|LINE|
+------+--------+--------+---+----+------+------+----+----+----+----+-+----+
|   630|    6ff8|    6fb9|  1|   8|220340|6c0a40|   1|1800|  32|   5|0|   0|
|   630|    6ff8|    6fb9|  1|   8|220340|6c0a40|   1|1800|  32|   5|0|   0|
|   630|    6ff8|    6fb9|  1|   8|2203a0|6c0a40|   1|1800|  31|   5|0|   0|
|   630|    6ff8|    6fb9|  1|   8|2203a0|6c0a40|   1|1800|  31|   5|0|   0|
+------+--------+--------+---+----+------+------+----+----+----+----+-+----+
```

Slot 1… port 79

Interface fc1/79

Src ID

FCID of sender

Dest ID

FCID of destination

Delay (msec)

Age of frame before it was dropped

Captures the last 4 packets dropped due to timeout per port

Troubleshooting SAN Congestion

Troubleshooting SAN Congestion

3 Step Process

1. Understand goals
2. Classify problem
3. Follow methodology

Troubleshooting SAN Congestion

Goals

Two main troubleshooting goals

1. Primary - Determine the culprit
2. Secondary – Determine the various victims

Culprits and Victims

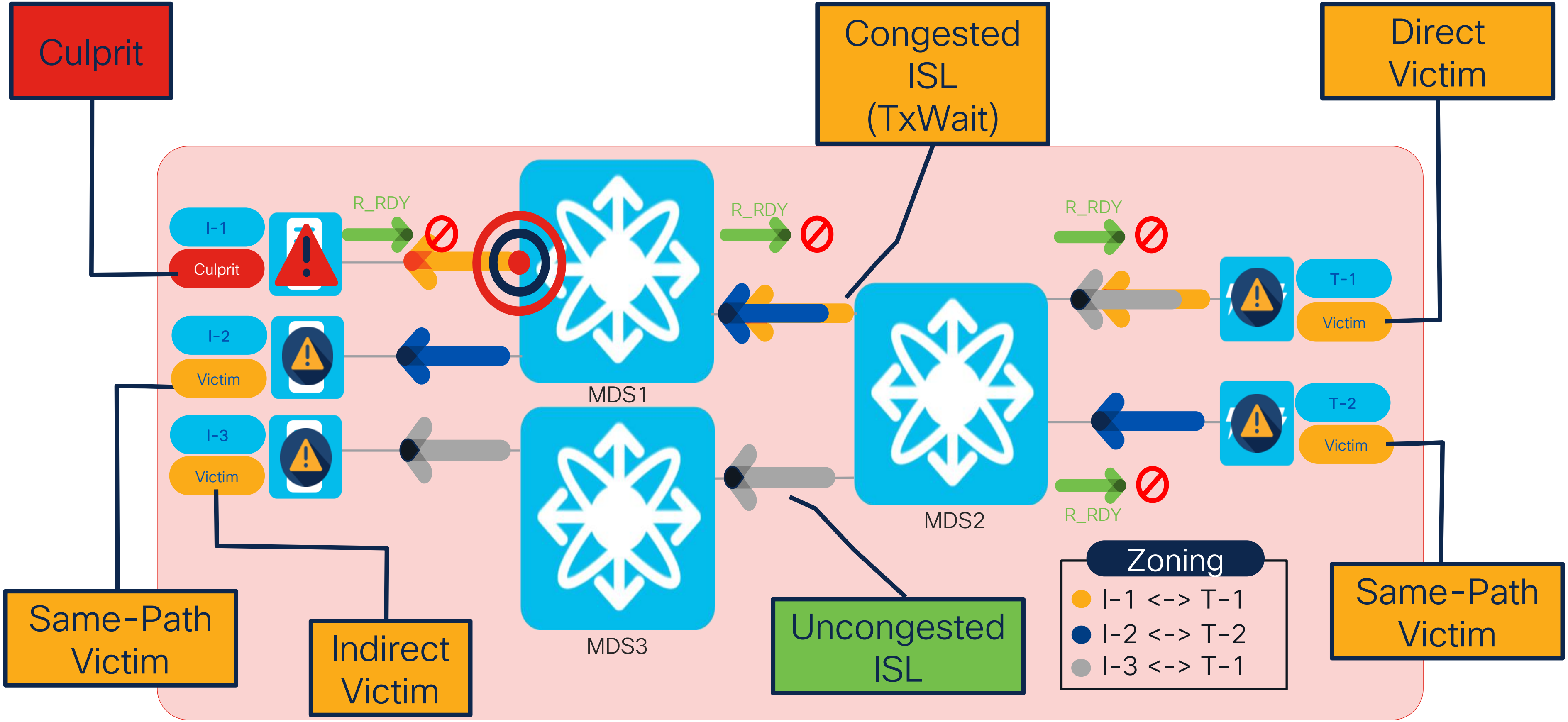
New terminology to describe devices causing problems and those affected

- **Culprits**
  - Those devices causing congestion
- **Victims**
  - Those devices affected by the congestion
  - Three types

1. **Direct** – Devices zoned with the culprit
2. **Indirect** – Devices zoned with the "direct victim"
3. **Same-path** – Devices utilizing the congested network path

Understanding culprits and victims explains the scope of the congestion

Culprit/Victim Identification



Troubleshooting SAN Congestion

Victim Identification

To identify the victims(and there will be many) first understand culprit zoning

Zone members will be ‘**Direct Victims**’

```
zone name I-1-T-1
member I-1 init
member T-1 target
```

I-1 is Culprit

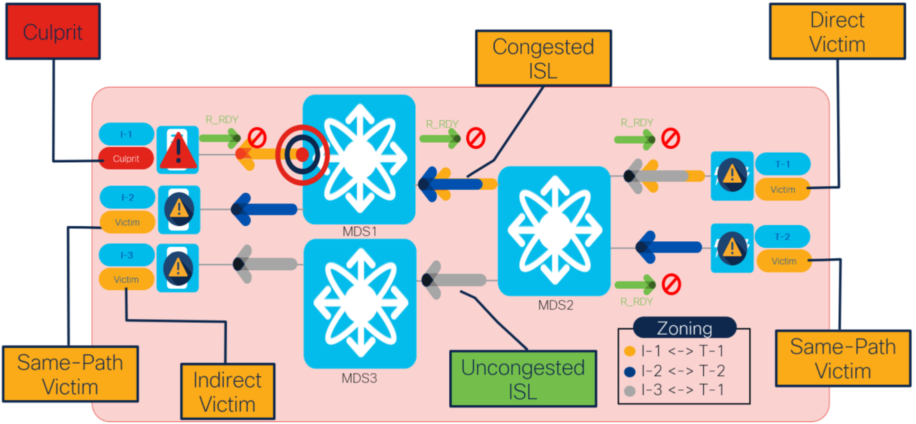
T-1 is Direct Victim

Zone members of ‘**Direct Victims**’ will be ‘**Indirect Victims**’

```
zone name I-3-T-1
member I-3 init
member T-1 target
```

I-3 is Indirect Victim of T-1

Culprit/Victim Identification



Identify congested path(s)

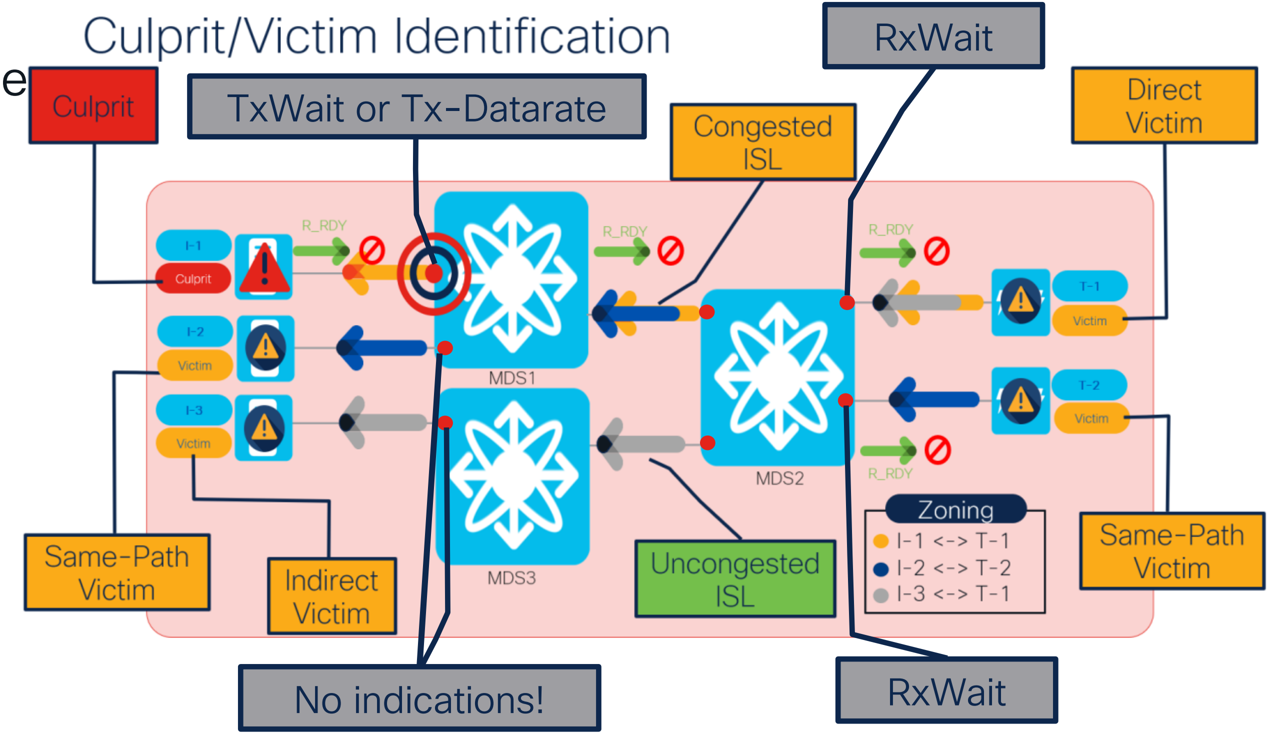
- All devices utilizing congested paths (e.g. All devices on MDS1) are potential ‘**Same-Path Victims**’

Troubleshooting SAN Congestion

Victim Identification

Next look for congestion indications

- Culprits
  - TxWait or Tx-Datarate
- Direct Victims
  - RxWait
- Indirect Victims
  - None
- Same-Path Victims
  - Sender – RxWait
  - Receiver – None



Troubleshooting SAN Congestion

Classifying Congestion Symptoms

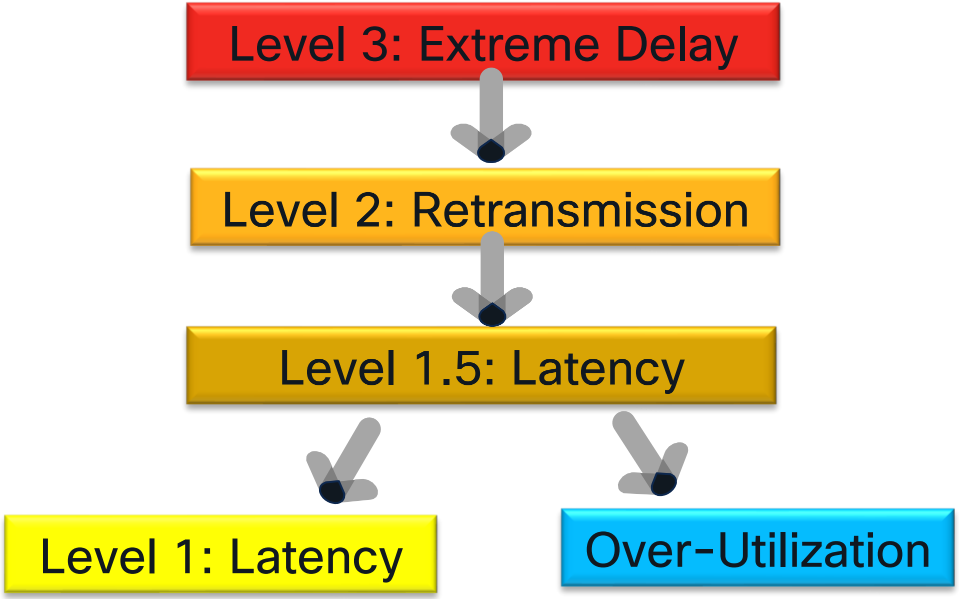
Level	Host Symptoms	Switch Behavior	Indications	Applicable Commands
1	Latency	Frame queuing	TxWait < 30% – Culprits, ISLs RxWait – Victims, ISLs	show interface <counters> show logging onboard txwait show logging onboard rxwait
1.5	Severe latency	Frame queuing	TxWait >= 30% – Culprits, ISLs RxWait – Victims, ISLs	Same as Level 1
Over-Utilization	Latency	Frame queuing	High Tx-Datarate - Culprits RxWait – Victims, ISLs TxWait - ISLs	Same as level 1/1.5 + show logging onboard datarate
2	SCSI errors / retransmissions	Frame dropping	TxWait – Culprits, ISLs RxWait – Victims, ISLs Timeout-drops – Culprits, ISLs	Same as level 1/1.5 + Show logging onboard error-stats
3	Extreme Delay / Application Failures	Links failing/reset (FC only)	TxWait – Culprits, ISLs RxWait – Victims, ISLs Timeout-drops, Culprits, ISLs Credit-Loss-Recovery, Culprits, ISLs Link Failures due to LR failures	Same as level 2 + show logging onboard credit-loss

Note: Each level includes all the symptoms of the previous levels

Troubleshooting SAN Congestion

Methodology

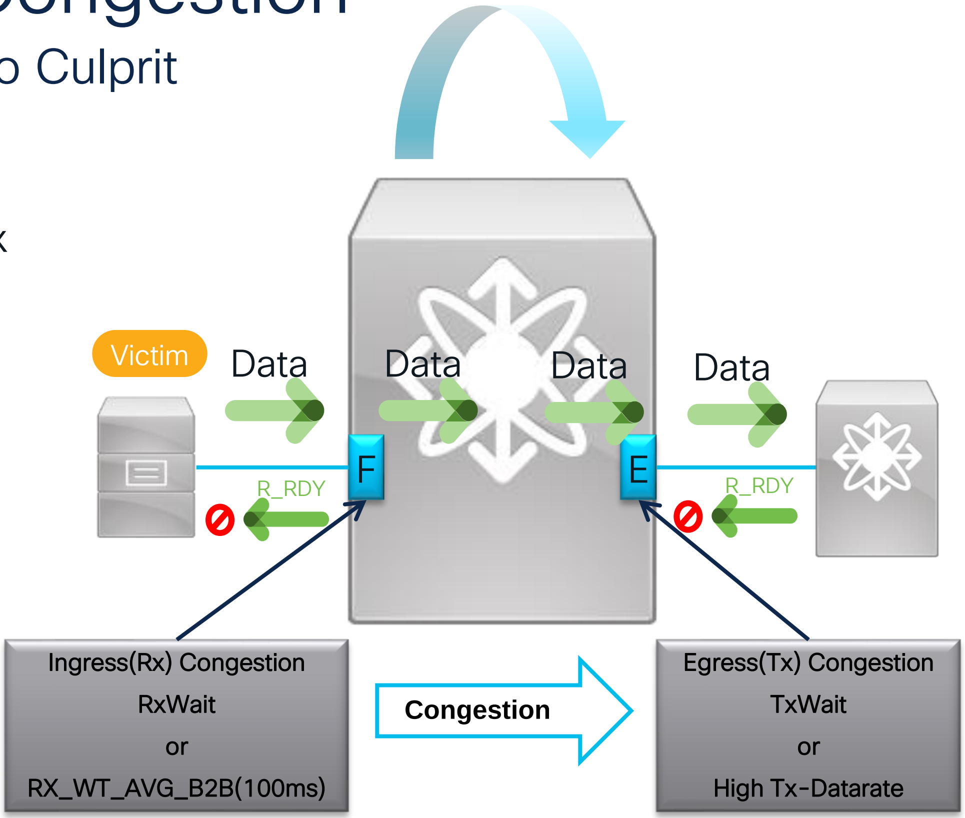
- Cisco recommends troubleshooting congestion in the following order:



Troubleshooting SAN Congestion

Methodology – Follow Congestion to Culprit

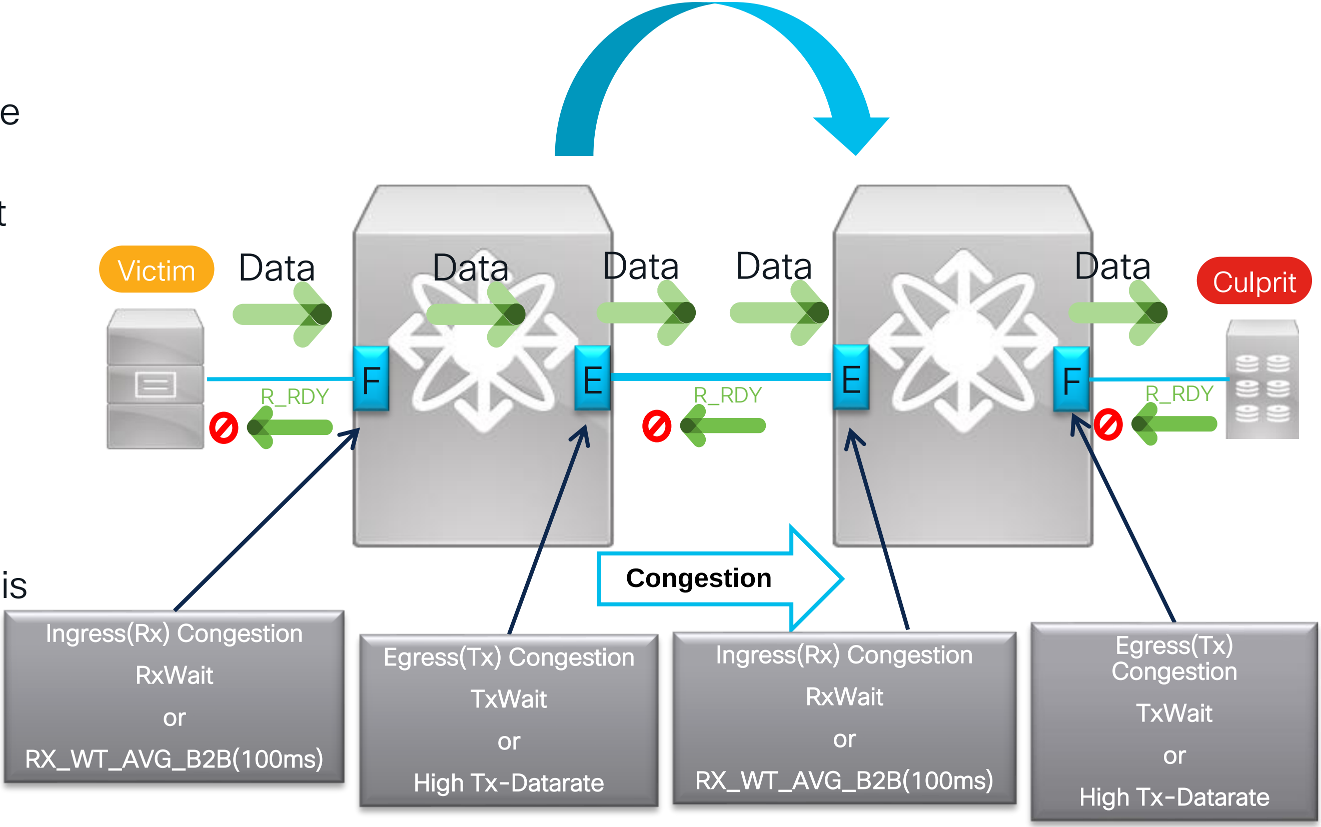
- If Rx congestion, then find ports communicating with this port that have Tx congestion
  - Zoning defines which devices communicate with this port
  - Understand topology
- If port communicating with port showing Rx congestion is FCIP
  - Check for TCP retransmits
  - Check for overutilization of FCIP



Troubleshooting SAN Congestion

Methodology - Follow Congestion to Culprit

- If Tx congestion found
  - If TxWait on F port then device attached is slow drain device
  - If High Tx-Utilization on F port then attached device has Over-Utilization Note: No TxWait in this case!
  - If E port then go to adjacent switch and continue troubleshooting
  - Continue to track through the fabric until destination F-port is discovered



Troubleshooting SAN Congestion

Now that I've located the culprit, what's next?

- For Level 1 1.5 2 problems:
  - Investigate end device for internal bottlenecks causing the TxWait
  - Go to Prevention section
- For OU Over-utilization problems:
  - Increase speed of HBA(e.g. 16Gbps to 32Gbps)
  - Increase number of HBAs
  - Implement storage array based initiator rate limiting
  - Go to Prevention section
- For Level 3 problems
  - Determine if due to severe congestion on end device
  - Determine if due to lost B2B credits due to physical(bit) errors
  - Consider port-monitor to error-disable

Troubleshooting SAN Congestion

Determining cause of level 3 congestion

- Physical errors - Look for evidence of bit errors (switch side)

```
MDS9132T# show interface fc1/13 counters detailed
fc1/13
...
 Link Stats:
...
   Rx Primitive sequence protocol errors:                               0
   Rx Invalid transmission words:                                       0
   Rx Invalid CRCs:                                                     0
   Rx Delimiter errors:                                                 0
   Rx fragmented frames:                                                0
   Rx frames with EOF aborts:                                           0
   Rx unknown class frames:                                             0
   Rx Runt frames:                                                      0
   Rx Jabber frames:                                                    0
   Rx too long:                                                         0
   Rx too short:                                                        0
   Rx FEC corrected blocks:                                             0
   Rx FEC uncorrected blocks:                                           0
...
   BB_SCs credit resend actions:                                        0
   BB_SCr Tx credit increment actions:                                  0
```

These counters indicate various types of bit errors

These two counters indicate B2B credits have been lost due to bit errors and recovered

Bit errors can cause a loss of B2B credits

Troubleshooting SAN Congestion

Determining cause of level 3 congestion - Continued

Physical errors – Check transceiver(SFP) power levels (switch side)

```
MDS9710# show interface fc10/1 transceiver details
fc10/1 sfp is present
 ...
    Cisco pid is DS-SFP-FC64G-SW
    Firmware version is 0.149

    No tx fault, no rx loss, in sync state, diagnostic monitoring type is 0x68
    SFP Diagnostics Information:
----------------------------------------------------------------------------
                                     Alarms                  Warnings
                                High        Low         High          Low
----------------------------------------------------------------------------
  Temperature   30.60 C          75.00 C     -5.00 C     70.00 C        0.00 C
  Voltage        3.29 V           3.63 V      2.97 V      3.46 V        3.13 V
  Current        7.00 mA         12.00 mA     3.00 mA    11.20 mA       3.60 mA
  Tx Power       0.58 dBm         5.00 dBm  -12.20 dBm    4.00 dBm     -8.20 dBm
  Rx Power     -12.36 dBm -       5.00 dBm  -15.20 dBm    2.00 dBm    -11.20 dBm
  Transmit Fault Count = 0
----------------------------------------------------------------------------
  Note: ++  high-alarm; +  high-warning; --  low-alarm; -  low-warning
```

fc10/1 has Rx Power(low light level) below the “Low Warning” threshold

Troubleshooting SAN Congestion

Determining cause of level 3 congestion

- Physical errors – Look for evidence of bit errors (adjacent side)

```
MDS# show rdp fcid 0xc90280 vsan 200
-------------------------------------------------------------
                   RDP frame details
-------------------------------------------------------------
…
Link Error Status:
------------------------------
VN PHY port type                 : FC
Link failure count               : 2
Loss of sync count               : 3
Loss of signal count             : 3
Primitive sequence proto error   : 0
Invalid Transmission word        : 0
Invalid CRC count                : 0
...
FEC Status:
------------------------------
Corrected blocks     : 0
Uncorrected blocks   : 0
```

These counters indicate various types of bit errors on the adjacent device

These counters indicate Forward Error Correction(FEC) errors on the adjacent device

RDP – Read Diagnostic Parameters – Queries stats from adjacent device

Troubleshooting SAN Congestion

Determining cause of level 3 congestion - Continued

Physical errors – Check transceiver(SFP) power levels on adjacent side

```
  MDS# show rdp fcid 0xc90280 vsan 200
  ------------------------------------------------------------
                     RDP frame details
  ------------------------------------------------------------
…
Optical Product Data:
------------------------------
Vendor Name     : AVAGO
…
  ---------------------------------------------------------------------------
                Current              Alarms                     Warnings
                Measurement     High        Low           High          Low
  ---------------------------------------------------------------------------
  Temperature   49.01 C         75.00 C     -5.00 C       70.00 C        0.00 C
  Voltage        3.36 V          3.61 V      2.97 V        3.46 V        3.10 V
  Current        7.50 mA         9.73 mA     1.54 mA       8.19 mA       2.56 mA
  Tx Power       0.73 dBm        5.39 dBm  -15.92 dBm      2.34 dBm     -9.90 dBm
  Rx Power      -1.09 dBm        3.38 dBm  -12.91 dBm      2.34 dBm    -11.15 dBm
  ---------------------------------------------------------------------------
  Note: ++  high-alarm; +  high-warning; --  low-alarm; -  low-warning
```

RDP shows adjacent SFP Rx and Tx power values look OK

Troubleshooting SAN Congestion

Determining cause of level 3 congestion - Continued

Physical errors – Ensure B2B State Change(BB_SC) is functional
BB_SC is a B2B credit recovery mechanism to recover 'lost' credits

```
MDS9710# show interface fc9/2
fc9/2 is up
    Hardware is Fibre Channel, SFP is short wave laser w/o OFC (SN)
…
    Port mode is F
    Port vsan is 1
    Admin Speed is auto
    Operating Speed is 32 Gbps
    Rate mode is dedicated
    Port flow-control is R_RDY

    Transmit B2B Credit is 32
    Receive B2B Credit is 32
    B2B State Change: Admin(on), Oper(up), Negotiated Value(14)
```

BB_SC is operational

If operational state is down check HBA settings

BB_SC is configured on

BB_SC can recover B2B credits prior to a total loss

Troubleshooting SAN Congestion

Determining cause of level 3 congestion - Continued

If any physical errors are found or SFP levels are low, check and/or replace:

- SFP (switch side)
- SFP (adjacent side)
- Cable(s)
- Ensure cables do not exceed length for cable type, SFP type and speed
- Patch panels(if any)

If no physical errors are found:

- Investigate end device for reasons for severe congestion

Consider using port-monitor to error-disable on counter credit-loss-reco

Tip: Credit-loss-recovery only on a single fabric's connection usually means problems with the physical connection

Credit-loss-recovery on both fabrics' connections usually means severe congestion in the end device(initiator or target)

SAN Congestion Alerting

Automated Alerting and Congestion Prevention

Port-monitor (PMon) on Cisco MDS

PMon monitors each switchport at a low granularity (as low as 1 second).

When a threshold exceed, PMon automatically takes actions like generating alerts, shutting down (errdisable) ports, flapping the port, isolating the port, or Dynamic Ingress Rate Limiting(DIRL).

Port-monitor has 23 counters that can be monitored

Port-monitor has 9 congestion related counters that can be monitored

Automated Alerting and Congestion Prevention

Available Port-monitor Counters

```
credit-loss-reco          Monitor credit loss recovery counter
err-pkt-from-xbar         Monitor err-pkt-from-xbar counter
err-pkt-to-xbar           Monitor err-pkt-to-xbar counter
input-errors              Monitor input-errors counter
invalid-crc               Monitor invalid-crc counter
invalid-words             Monitor invalid-words counter
link-loss                 Monitor link-failure counter
lr-rx                     Monitor the number of link resets received by the fc-port
lr-tx                     Monitor the number of link resets transmitted by the fc-port
rx-datarate               Monitor rx performance counter
rx-datarate-burst         Monitor rx-datarate-burst counter
sfp-rx-power-low-warn     Monitor sfp receive power low warning
sfp-tx-power-low-warn     Monitor sfp transmit power low warning
signal-loss               Monitor signal-loss counter
state-change              Monitor state-change counter
sync-loss                 Monitor sync-loss counter
timeout-discards          Monitor timeout discards counter
tx-credit-not-available   Monitor credit not available counter
tx-datarate               Monitor tx performance counter
tx-datarate-burst         Monitor tx-datarate-burst counter
tx-discards               Monitor tx discards counter
tx-slowport-oper-delay    Monitor tx slow port operation delay
txwait                    Monitor tx total wait counter
```

Congestion

Counters in orange are congestion related
Level 1, 1.5, 2 and 3

Over-Utilization

tx-datarate and tx-datarate-burst **are needed** for detecting Over-Utilization
On by default in 8.5(1), 9.2(1) and later

Automated Alerting and Congestion Prevention

Port-monitor (PMon) on Cisco MDS

How to configure Port-Monitor?

1. Start by enabling Port-Monitor for sending alerts
2. Refine the thresholds over weeks/months. Solve the real culprits. Avoid too many alerts.
3. Finally, enable actions, such as congestion prevention using DIRL
4. Ensure tx-datarate and/or tx-datarate-burst are on for Over-Utilization!
5. Go to step 2

Sample PMon policies: https://www.cisco.com/c/en/us/support/docs/storage-networking/mds-9000-nx-os-software-release-62/200102-Sample-MDS-port-monitor-policy-for-alert.html

PMon Policy on MDS

```
#
port-monitor name fabricmon_edge_policy
  logical-type edge
 counter txwait poll-interval 1 delta rising-threshold 30 event 4 falling-threshold 10 event 4 alerts syslog rmon portguard DIRL
 counter tx-datarate poll-interval 10 delta rising-threshold 80 event 4 falling-threshold 70 event 4 alerts syslog rmon obfl portguard DIRL
 counter tx-datarate-burst poll-interval 10 delta rising-threshold 5 event 4 falling-threshold 1 event 4 alerts syslog rmon obfl datarate 90
```

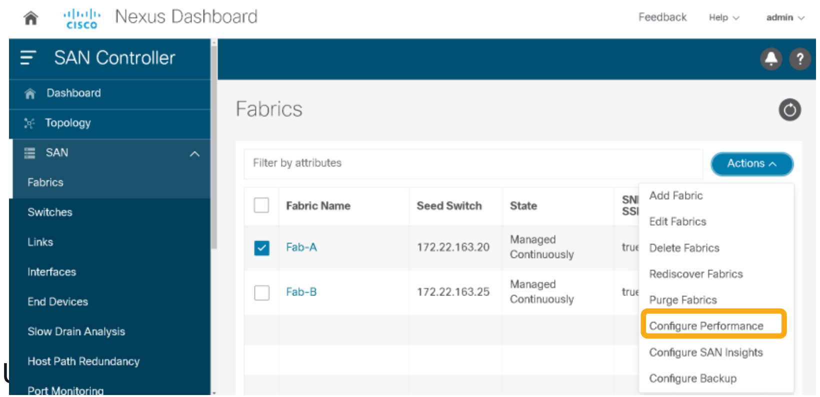
```
# Show port-monitor
Policy Name  : fabricmon_edge_policy
Admin status : Not Active
Oper status  : Not Active
Port type    : All Edge Ports
------------------------------------------------------------------------------------------------------------------------------------------------------------------
|         Counter          | Threshold  | Interval |      Warning       |      Thresholds       |             Rising/Falling actions                  | Congestion-signal |
|                          |    Type    |  (Secs)  |--------------------|-----------------------|-----------------------------------------------------|-------------------|
|                          |            |          | Threshold | Alerts |  Rising   | Falling   | Event |      Alerts        |       PortGuard       | Warning | Alarm   |
------------------------------------------------------------------------------------------------------------------------------------------------------------------
| Link Loss                | Delta      | 30       | none      | n/a    | 5         | 1         | 4     | syslog,rmon        | FPIN                  | n/a     | n/a     |
| Sync Loss                | Delta      | 30       | none      | n/a    | 5         | 1         | 4     | syslog,rmon        | FPIN                  | n/a     | n/a     |
| Signal Loss              | Delta      | 30       | none      | n/a    | 5         | 1         | 4     | syslog,rmon        | FPIN                  | n/a     | n/a     |
| Invalid Words            | Delta      | 30       | none      | n/a    | 1         | 0         | 4     | syslog,rmon        | FPIN                  | n/a     | n/a     |
| Invalid CRC's            | Delta      | 30       | none      | n/a    | 5         | 1         | 4     | syslog,rmon        | FPIN                  | n/a     | n/a     |
| State Change             | Delta      | 60       | none      | n/a    | 5         | 0         | 4     | syslog,rmon        | none                  | n/a     | n/a     |
| TX Discards              | Delta      | 60       | none      | n/a    | 200       | 10        | 4     | syslog,rmon        | none                  | n/a     | n/a     |
| LR RX                    | Delta      | 60       | none      | n/a    | 5         | 1         | 4     | syslog,rmon        | none                  | n/a     | n/a     |
| LR TX                    | Delta      | 60       | none      | n/a    | 5         | 1         | 4     | syslog,rmon        | none                  | n/a     | n/a     |
| Timeout Discards         | Delta      | 60       | none      | n/a    | 200       | 10        | 4     | syslog,rmon        | none                  | n/a     | n/a     |
| Credit Loss Reco         | Delta      | 1        | none      | n/a    | 1         | 0         | 4     | syslog,rmon        | none                  | n/a     | n/a     |
| TX Credit Not Available  | Delta      | 1        | none      | n/a    | 10%       | 0%        | 4     | syslog,rmon        | none                  | n/a     | n/a     |
| RX Datarate              | Delta      | 10       | none      | n/a    | 80%       | 70%       | 4     | syslog,rmon,obfl   | none                  | n/a     | n/a     |
| TX Datarate              | Delta      | 10       | none      | n/a    | 80%       | 70%       | 4     | syslog,rmon,obfl   | DIRL                  | n/a     | n/a     |
| TX-Slowport-Oper-Delay   | Absolute   | 1        | none      | n/a    | 50ms      | 0ms       | 4     | syslog,rmon        | none                  | n/a     | n/a     |
| TXWait                   | Delta      | 1        | none      | n/a    | 30%       | 10%       | 4     | syslog,rmon        | DIRL                  | 40%     | 60%     |
| RX Datarate Burst        | Delta      | 10       | none      | n/a    | 5@90%     | 1@90%     | 4     | syslog,rmon,obfl   | none                  | n/a     | n/a     |
| Input Errors             | Delta      | 60       | none      | n/a    | 5         | 1         | 4     | syslog,rmon        | none                  | n/a     | n/a     |
------------------------------------------------------------------------------------------------------------------------------------------------------------------
 On falling threshold portguard actions FPIN, DIRL, Cong-Isolate-Recover will initiate auto recovery of ports.
```

NDFC Congestion/Congestion Analysis

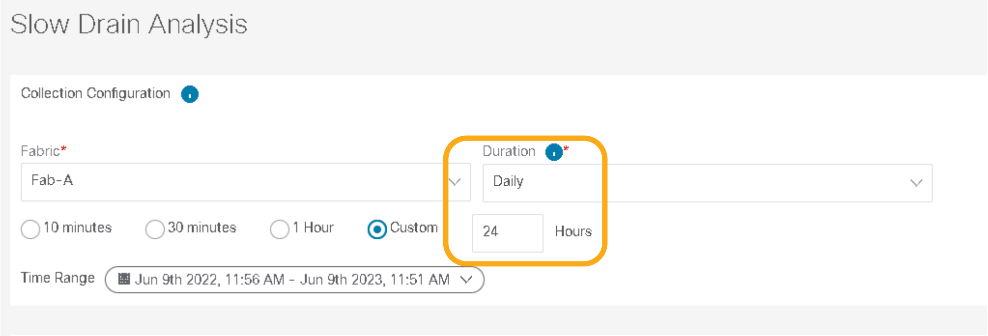
Best Practice – Run in always-on mode.

- Slow-drain analysis is not enabled by default

- After adding a new fabric:
  - Enable performance monitoring
  - Schedule to run slow drain analysis daily for 24 hou



	Fabric Name	Seed Switch	State	SN SS
☑	Fab-A	172.22.163.20	Managed Continuously	true
□	Fab-B	172.22.163.25	Managed Continuously	true


Slow Drain Analysis

Collection Configuration

Fabric*: Fab-A

Duration*: Daily

○ 10 minutes ○ 30 minutes ○ 1 Hour ● Custom

24 Hours

Time Range: Jun 9th 2022, 11:56 AM - Jun 9th 2023, 11:51 AM

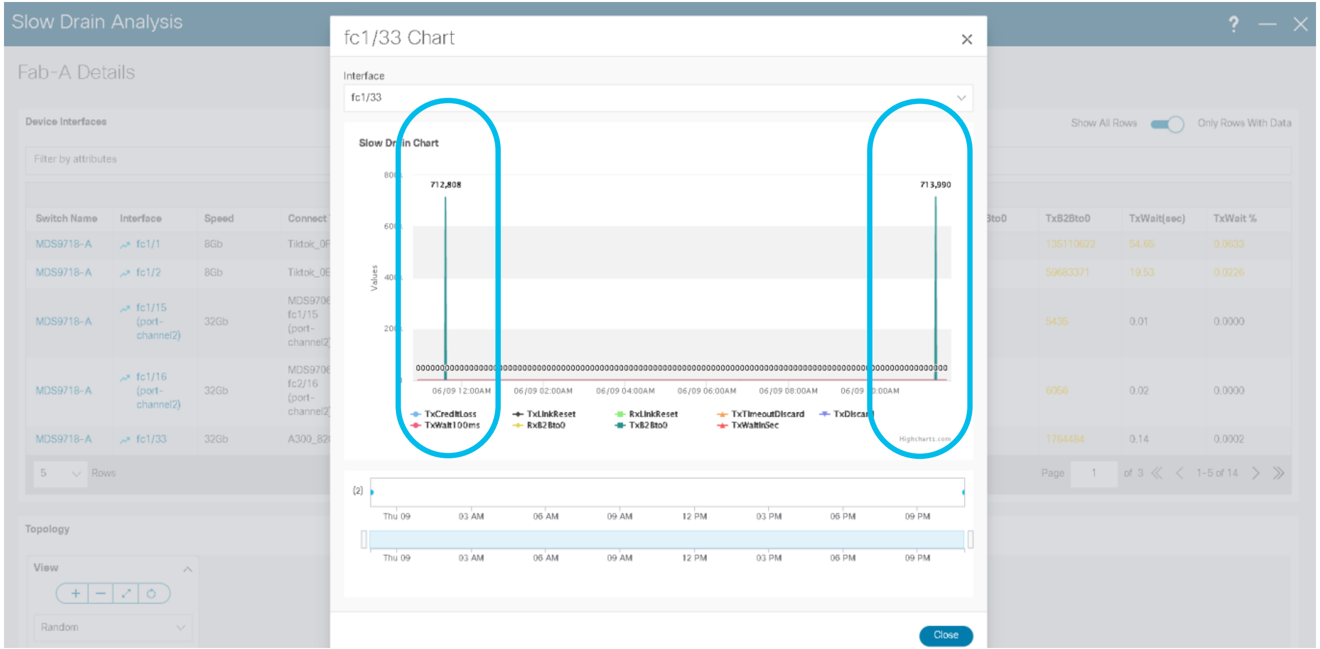
*Slow-drain Analysis is renamed to Congestion Analysis in NDFC 12.1.1e

- DCNM/NDFC slow-drain analysis has minimal/negligible effect on the switches

NDFC Congestion/Slow-drain Analysis

Always-on, historical view with trending and seasonality

- fc1/33 is congested in Tx direction
- TxWait increases but not all the time. Only two spikes in last 12 hours.
- Next Steps –
  - Correlate with host and app. Does it correlate with a cron job on the host?
  - Look at SAN Insights metrics to find the root cause.



Slow Drain Analysis

Fab-A Details

Device Interfaces

Filter by attributes

Show All Rows ● Only Rows With Data

Switch Name	Interface	Speed	Connect	Bto0	TxB2Bto0	TxWait(sec)	TxWait %
MDS9718-A	fc1/1	8Gb	Tiktok_0F		135110622	54.65	0.0633
MDS9718-A	fc1/2	8Gb	Tiktok_0E		59683371	19.53	0.0226
MDS9718-A	fc1/15 (port-channel2)	32Gb	MDS9706 fc1/15 (port-channel2		5435	0.01	0.0000
MDS9718-A	fc1/16 (port-channel2)	32Gb	MDS9706 fc2/16 (port-channel2		6056	0.02	0.0000
MDS9718-A	fc1/33	32Gb	A300_82		1764484	0.14	0.0002

5 Rows

Page 1 of 3 1-5 of 14

Topology

View

Random

fc1/33 Chart

Interface: fc1/33

Slow Drain Chart

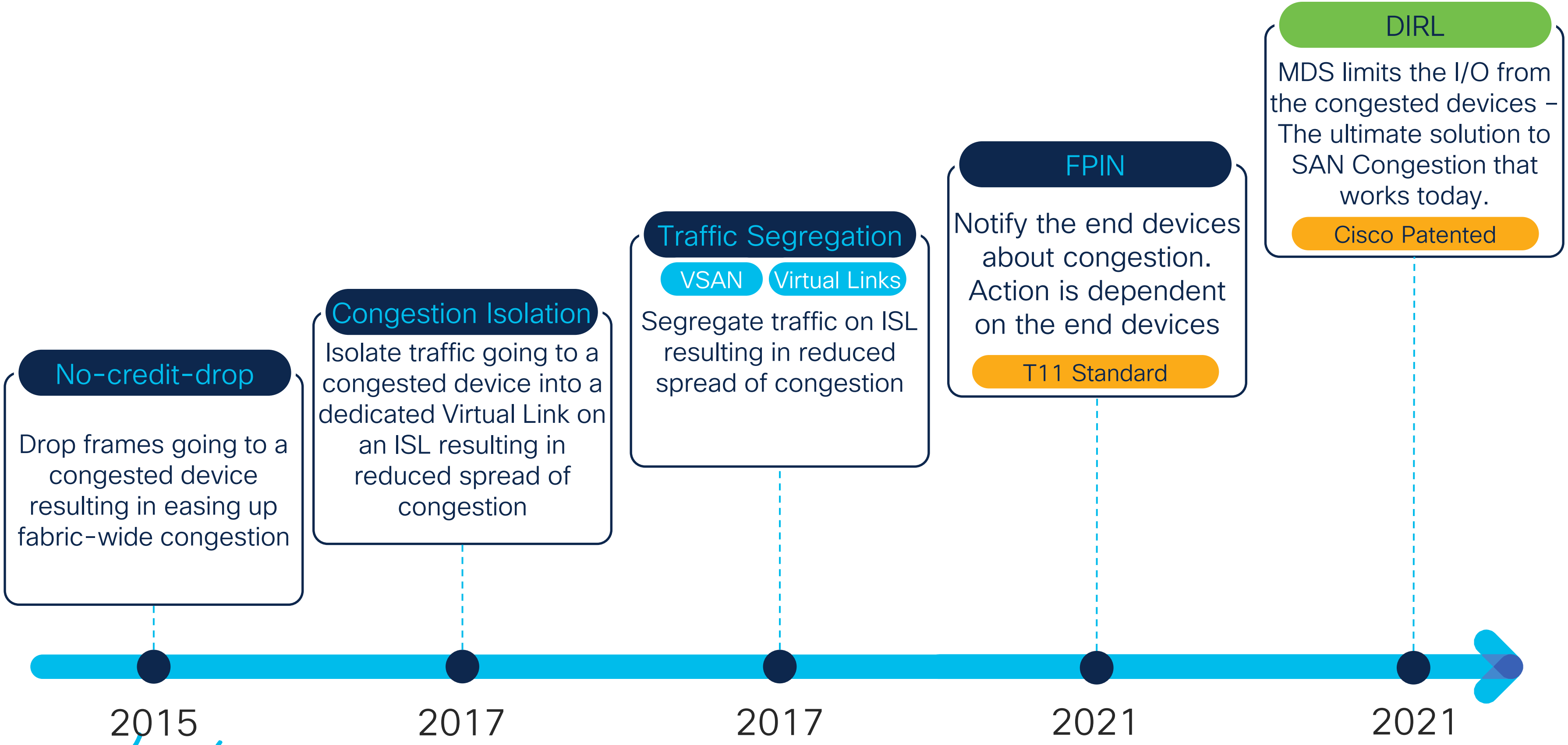
SAN Congestion Preventing

SAN Congestion

Including Slow Drain and Over-Utilization

We talked about
Understanding,
Detection,
Troubleshooting
and
Alerting
Now, let’s talk about Prevention

SAN Congestion Innovation on Cisco MDS



No-credit-drop

Drop frames going to a congested device resulting in easing up fabric-wide congestion

2015

Congestion Isolation

Isolate traffic going to a congested device into a dedicated Virtual Link on an ISL resulting in reduced spread of congestion

2017

Traffic Segregation

VSAN | Virtual Links

Segregate traffic on ISL resulting in reduced spread of congestion

2017

FPIN

Notify the end devices about congestion. Action is dependent on the end devices

T11 Standard

2021

DIRL

MDS limits the I/O from the congested devices – The ultimate solution to SAN Congestion that works today.

Cisco Patented

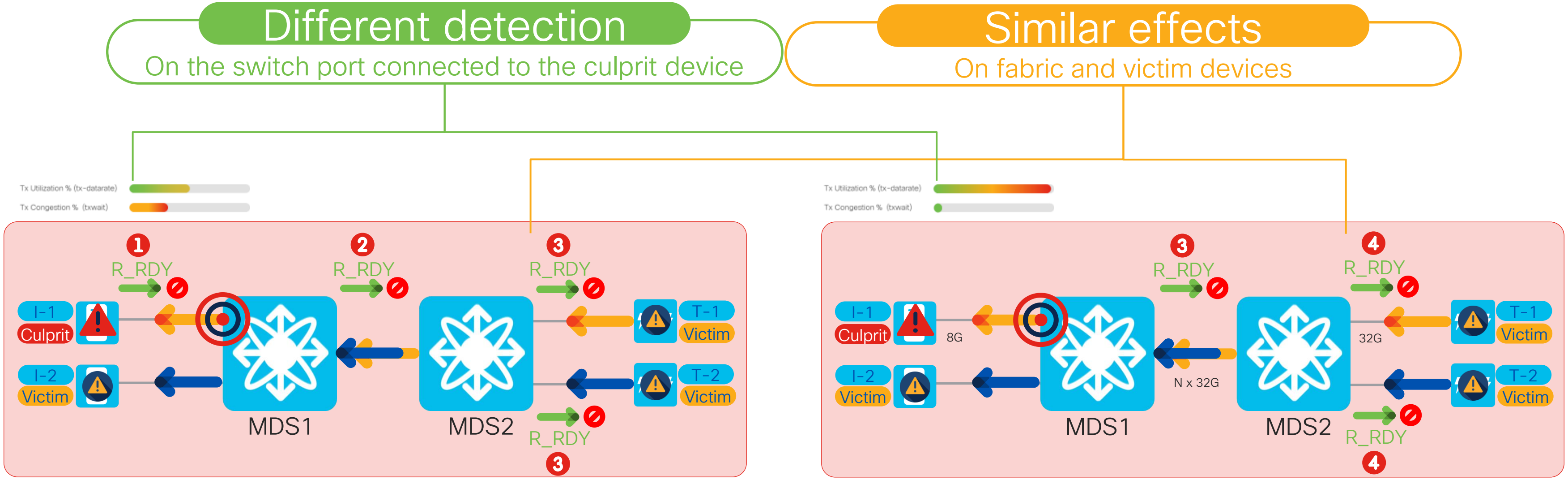
2021

Not an exhaustive list

Common Causes of SAN Congestion

Slow Drain

Over-Utilization



Different detection

On the switch port connected to the culprit device

Similar effects

On fabric and victim devices

Common Causes of SAN Congestion

Slow Drain

Over-Utilization

Different detection

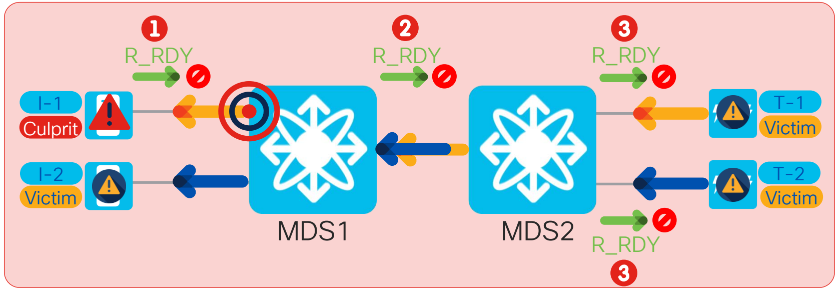
On the switch port connected to the culprit device

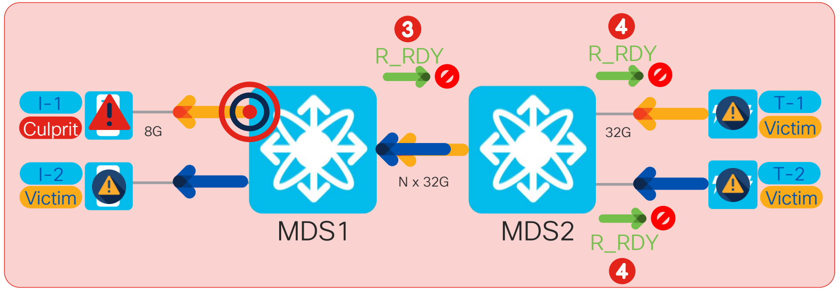
Similar effects

On fabric and victim devices

Same Root Cause

The culprit device is receiving more than it can ingest

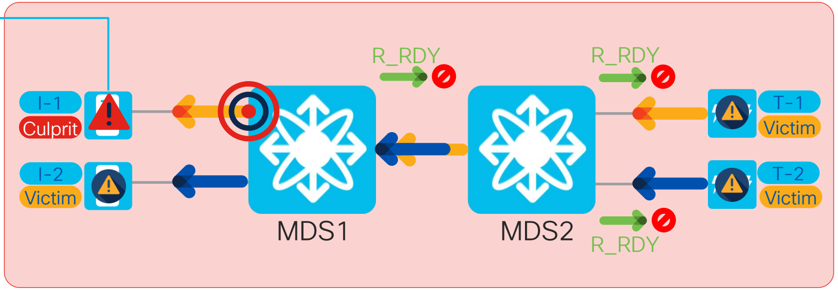




The Root Cause of SAN Congestion

The Root Cause

I-1 is receiving more than it can ingest



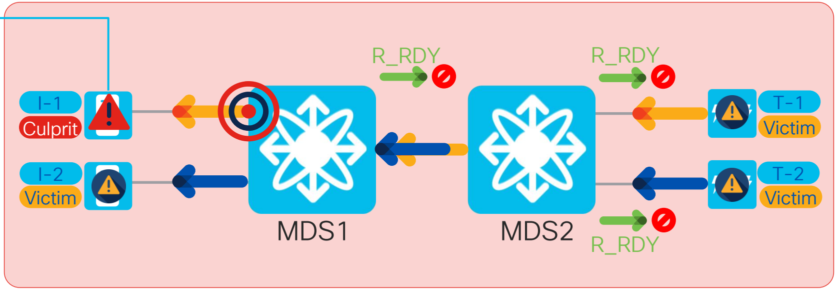
The Root Cause of SAN Congestion

The Root Cause

I-1 is receiving more than it can ingest

Why is I-1 receiving more than it can ingest?

...because I-1 is asking for it.



The Solution

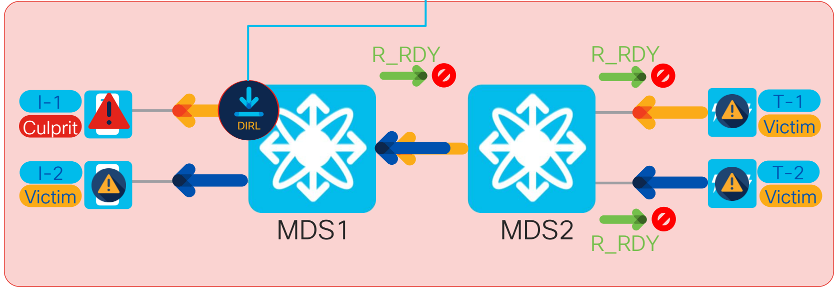
Cisco Dynamic Ingress Rate Limiting

DIRL

I-1 is asking for more than it can ingest

DIRL limits I-1's asking rate to reduce its receiving rate

DIRL dynamically changes I-1's *asking* rate to adapt to its traffic profile



The Solution

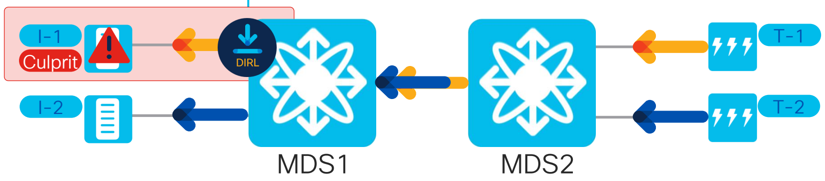
Cisco Dynamic Ingress Rate Limiting

DIRL

I-1 is asking for more than it can ingest

DIRL limits I-1's *asking* rate to reduce its receiving rate

DIRL dynamically changes I-1's *asking* rate to adapt to its traffic profile



DIRL prevents SAN Congestion due to slow-drain **and** over-utilization.

Cisco Dynamic Ingress Rate Limiting

End-device independent

Upgrading of end-devices is not needed

Adaptive

DIRL dynamically adjusts as per the traffic profile of the host

No side effects

Rate limits congested hosts only. Other non-congested hosts and storage ports are not impacted

Easy adoption

DIRL is available on MDS switches after a software-only upgrade.

Gradual Rollout

DIRL can be implemented one switch at a time

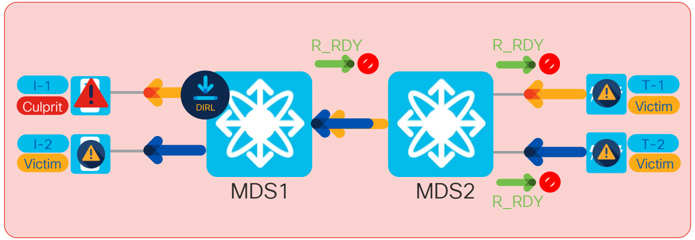
Affordable

No additional license needed

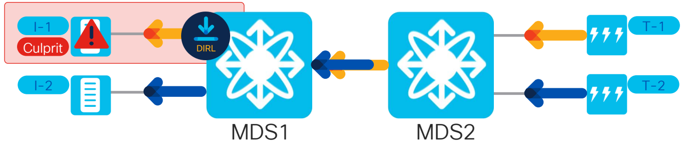
Topology independent

DIRL works in edge-core, edge-core-edge, or collapsed core (single switch fabric) topologies

Without Cisco DIRL

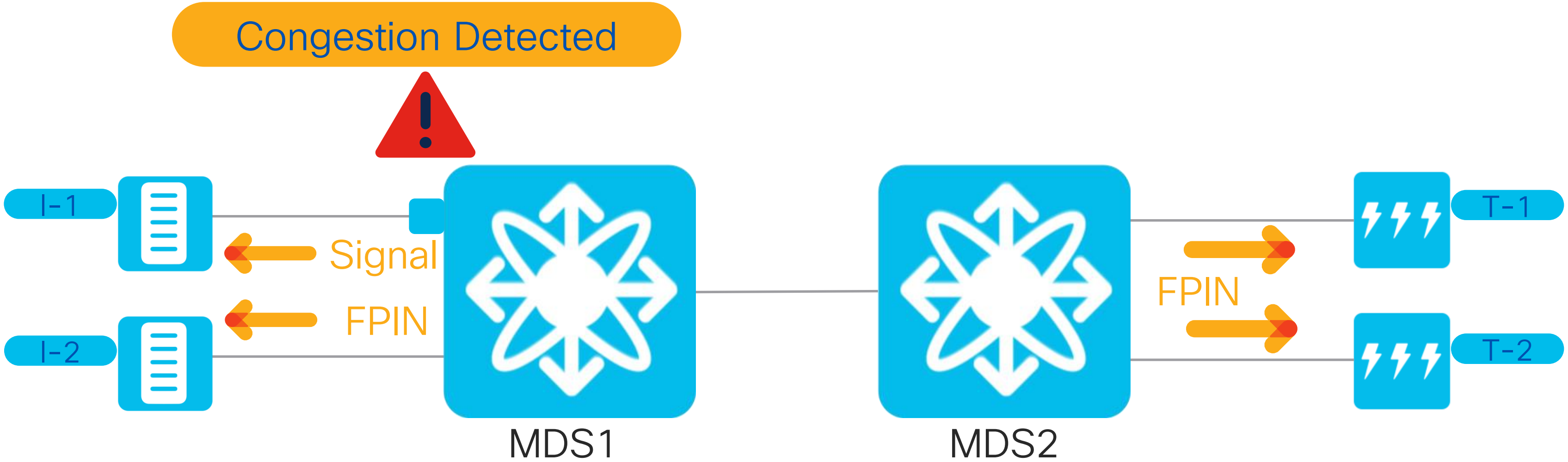


With Cisco DIRL



Back pressure alleviated!

Notifications and Congestion Signals in Fibre Channel

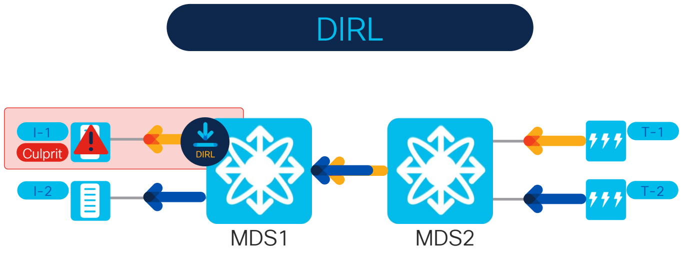


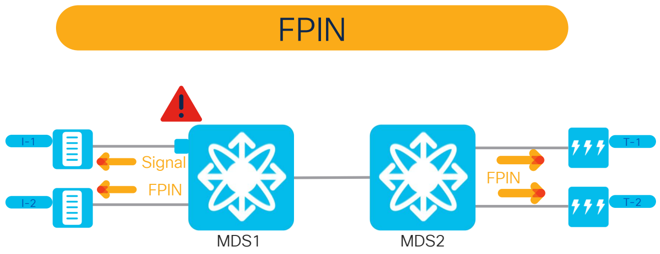
Available on Cisco MDS in NX-OS 8.5(1) onwards

Exchange Diagnostic Capabilities (EDC) (for Congestion Signals)
Register Diagnostic Functions (RDF) (for FPINs)
Congestion Signals (Primitives)
Fabric Performance Impact Notifications (FPIN)

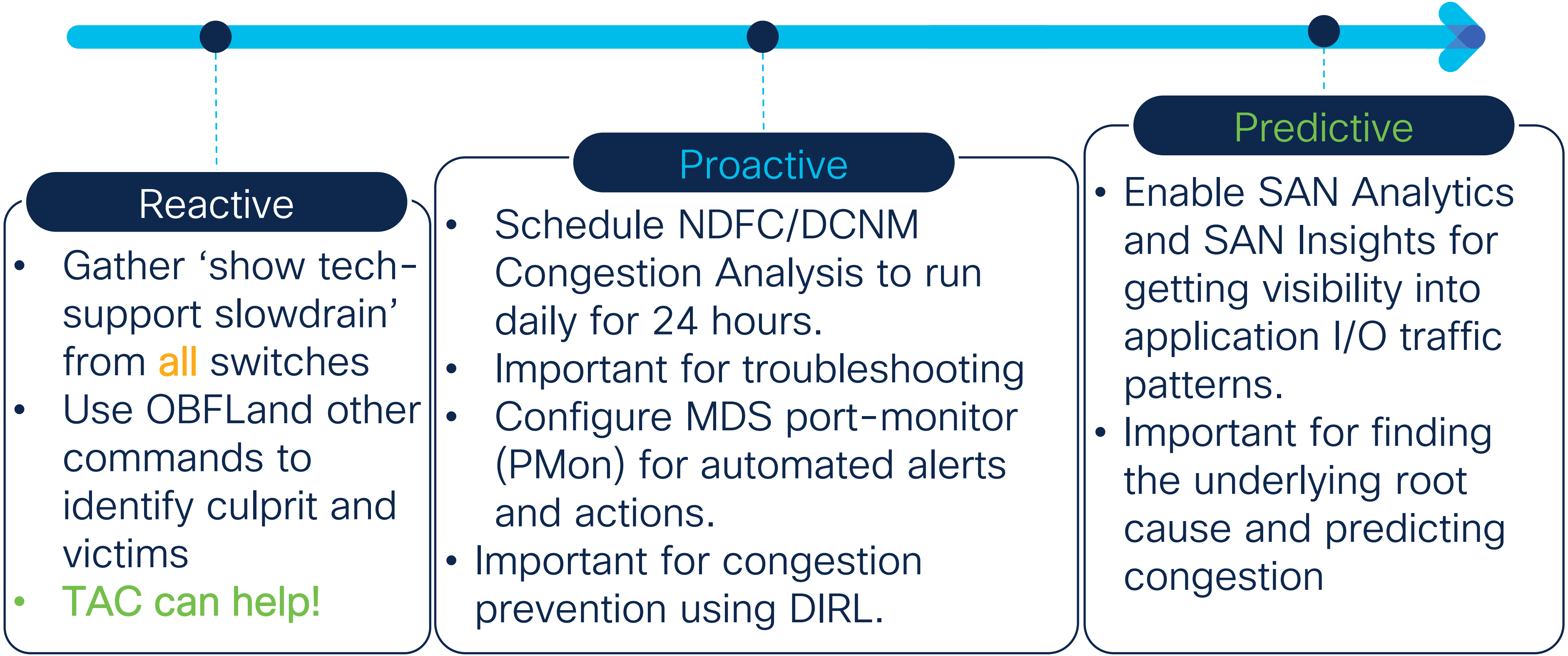
DIRL vs FPIN

- DIRL helps today. FPIN readiness will take a few years.
  - DIRL is available on existing MDS switch after a software-only upgrade, without any dependency on end devices
  - Although FPIN is supported on MDS switches, action is dependent on the end devices
- DIRL is affordable
  - DIRL and FPIN work on existing MDS switches and don’t need an additional license
  - Must upgrade end-devices to benefit from FPIN
- In the future, when you are ready for FPIN, DIRL will continue to be a complementary technology
  - What if a few devices don’t react to FPIN and still cause congestion? DIRL within MDS switches will be the protection





SAN Congestion Management - Recommendations



Reactive

- Gather ‘show tech-support slowdrain’ from all switches
- Use OBFLand other commands to identify culprit and victims
- TAC can help!

Proactive

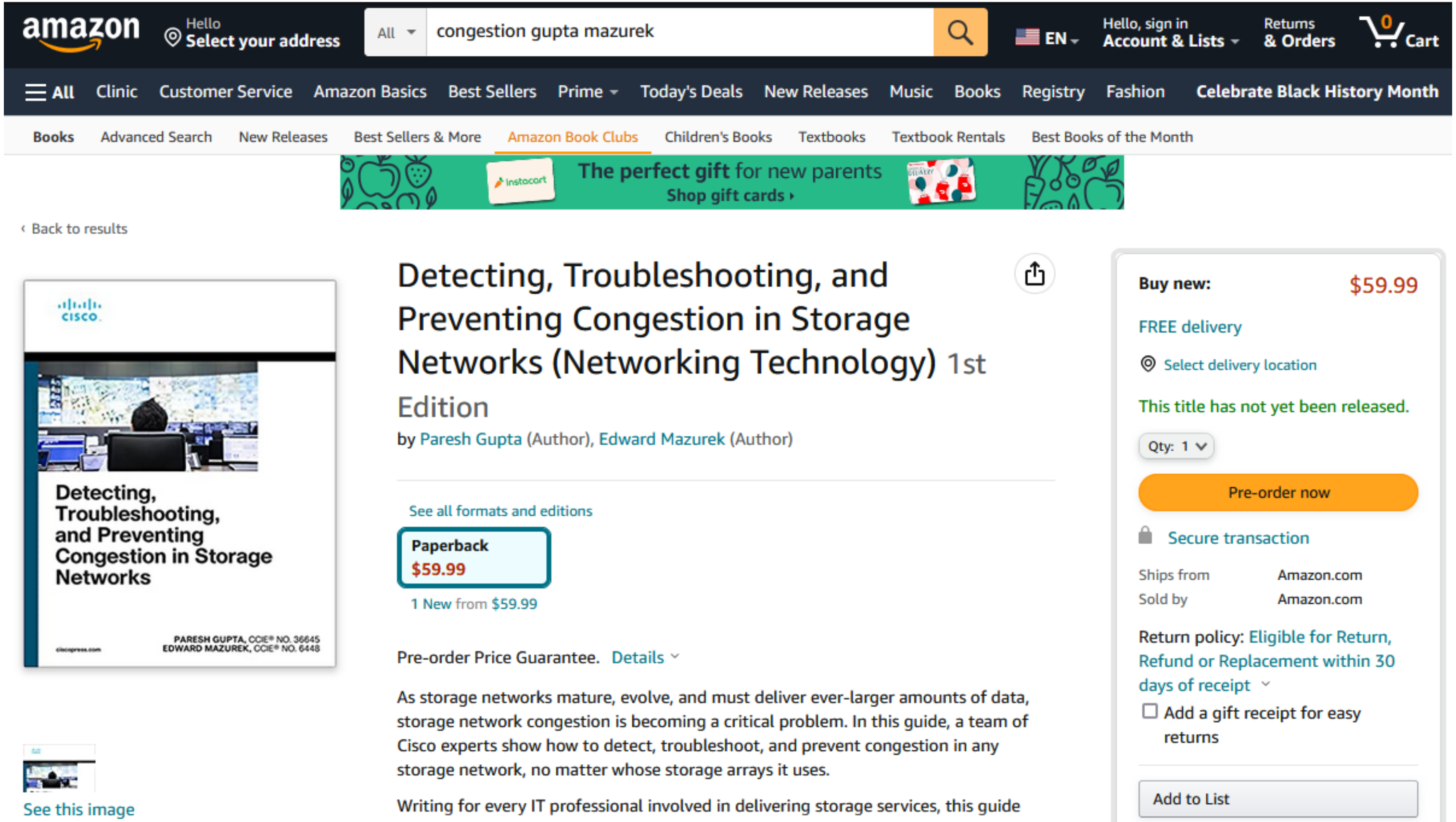
- Schedule NDFC/DCNM Congestion Analysis to run daily for 24 hours.
- Important for troubleshooting
- Configure MDS port-monitor (PMon) for automated alerts and actions.
- Important for congestion prevention using DIRL.

Predictive

- Enable SAN Analytics and SAN Insights for getting visibility into application I/O traffic patterns.
- Important for finding the underlying root cause and predicting congestion

*Slow-drain Analysis is renamed to Congestion Analysis in NDFC 12.1(1e)

Upcoming Book Available For Pre-order



Detecting, Troubleshooting, and Preventing Congestion in Storage Networks (Networking Technology) 1st Edition

by Paresh Gupta (Author), Edward Mazurek (Author)

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As storage networks mature, evolve, and must deliver ever-larger amounts of data, storage network congestion is becoming a critical problem. In this guide, a team of Cisco experts show how to detect, troubleshoot, and prevent congestion in any storage network, no matter whose storage arrays it uses.

Writing for every IT professional involved in delivering storage services, this guide

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BRKDCN-3677	Dos and Don't of Deploying NVMe Over Fabrics	Thursday, June 8, 1:00 PM – 2:00 PM	Kamal Bakshi

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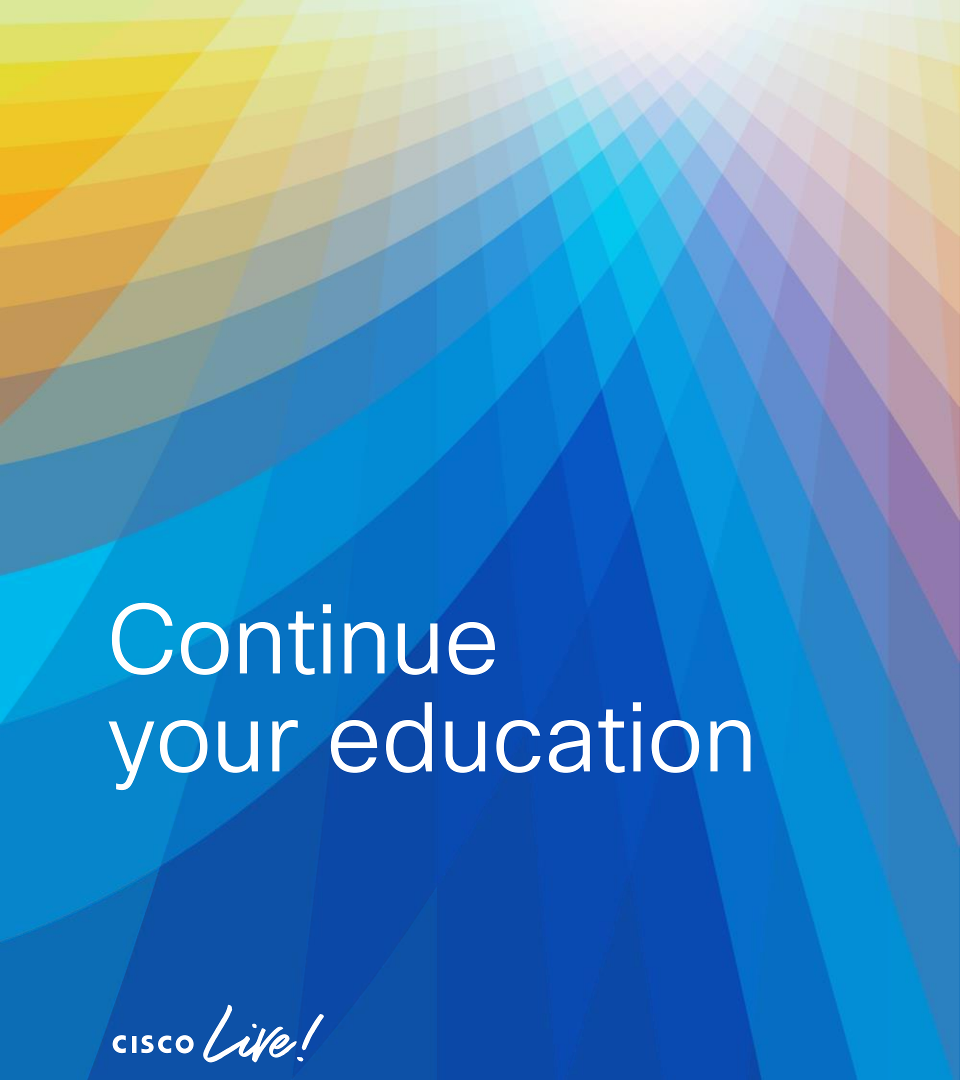
Attendees who fill out a minimum of four session surveys and the overall event survey will get **Cisco Live-branded socks** (while supplies last)!

Attendees will also earn 100 points in the **Cisco Live Challenge** for every survey completed.

These points help you get on the leaderboard and increase your chances of winning daily and grand prizes



Continue your education

- Visit the Cisco Showcase for related demos
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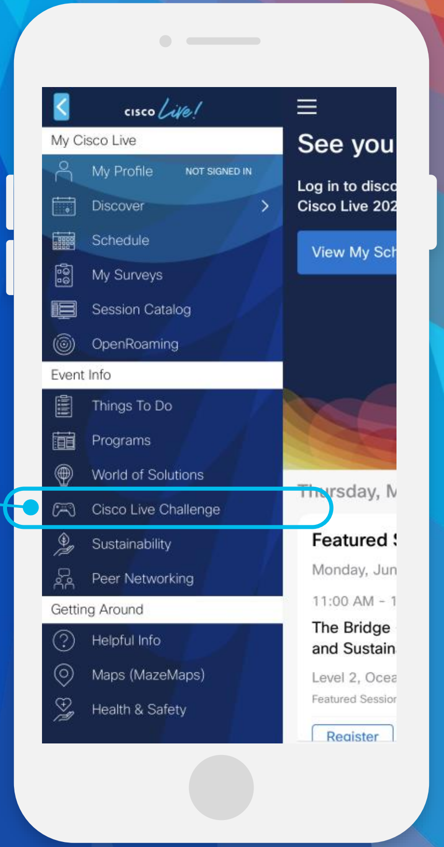
Cisco Live **Challenge**

Gamify your Cisco Live experience!

Get points for attending this session!

How:

1. Open the Cisco Events App.
2. Click on 'Cisco Live Challenge' in the side menu.
3. Click on View Your Badges at the top.
4. Click the + at the bottom of the screen and scan the QR code:



cisco Live!

Let’s go

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