The bridge to possible

Detecting, Alerting, Identifying and Proactively Preventing SAN Congestion

Getting your SAN to perform at its best

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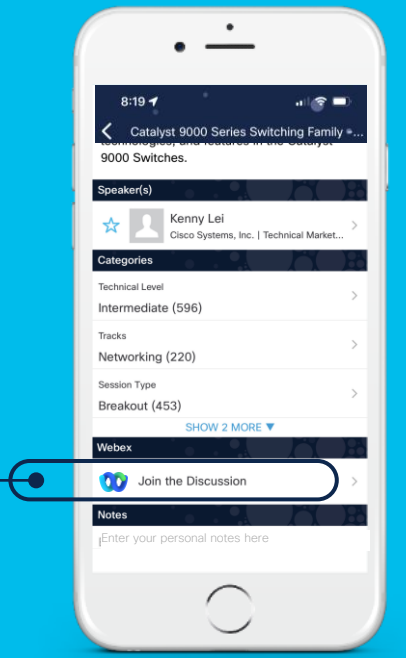


Agenda

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

Overview

What is this ‘SAN Congestion’ thing?

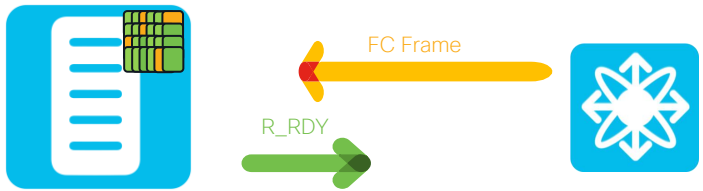
- Why am I referring to ‘SAN Congestion’ instead of ‘Slow Drain’?
- Everyone knows ‘Slow Drain’, so why ‘SAN Congestion’?
- Why should I be concerned?

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

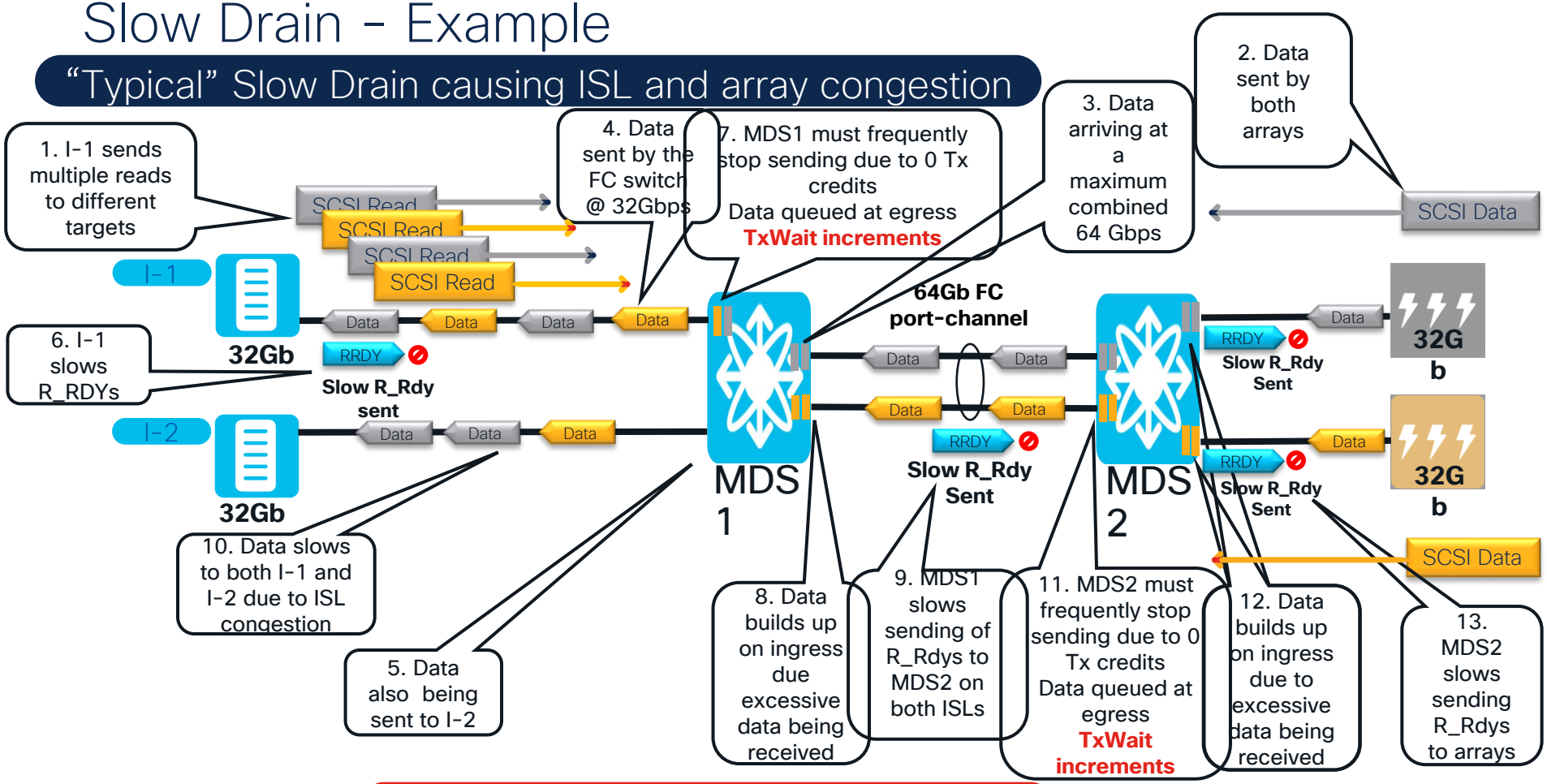
There are 4 main reasons for congestion in a Fibre Channel SAN

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 a little of #4 are the focus of this presentation

Slow Drain – Example

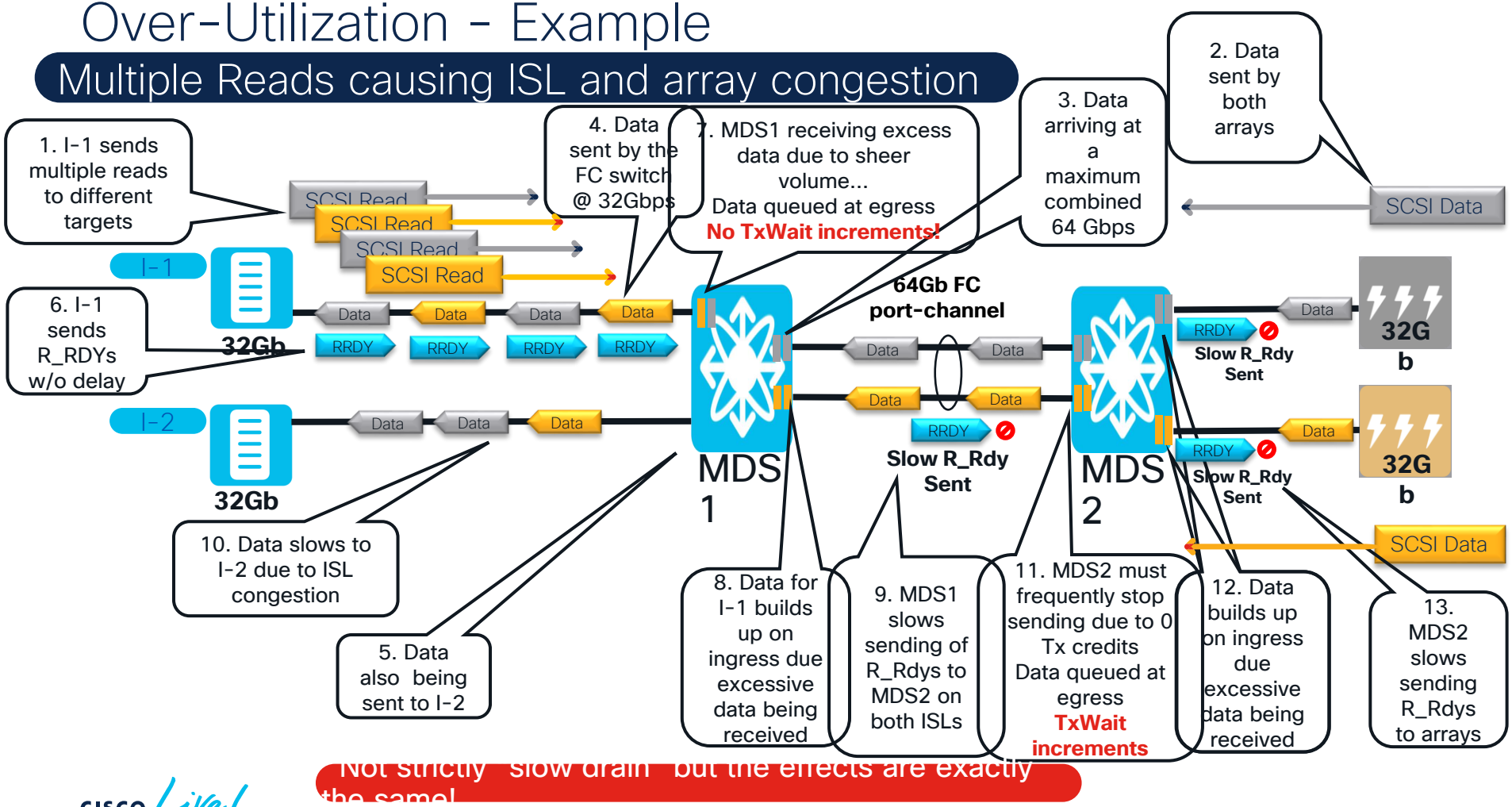
"Typical" Slow Drain causing ISL and array congestion



Both arrays and all devices utilizing ISLs are affected!

Over-Utilization – Example

Multiple Reads causing ISL and array congestion



Comparison of Slow Drain vs. Over-Utilization

Slow Drain

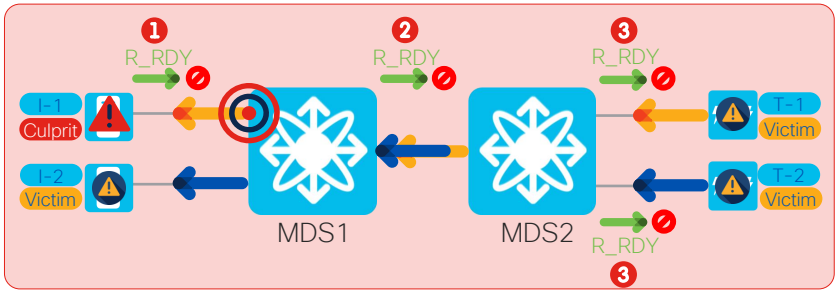
Tx B2B credit starvation

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

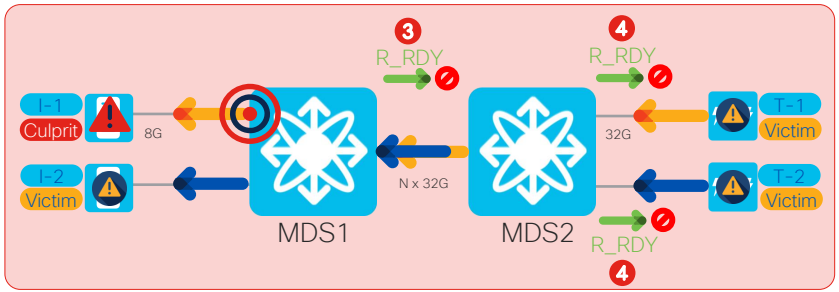
Receive data rate on ISL port is faster than the host port speed

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.

Logged individually per module

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

```
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 |
```

Understanding Tx-datarate – Port Utilization

- Tx-Datarate is the basic metric for determining **Over-Utilization**
- Port-monitor on MDS measures datarate in percent utilization. For example,
  - Tx-datarate: tx utilization >= 80% (*) continuously for 10 seconds (*)
  - Tx-datarate-burst: 5 (*) times in 10 seconds (*) tx utilization > 90% (*) continuously for 1 second

Fibre Channel speeds	Baud rate(GBd/s)	Bit Rate(Gb/s)	Data Rate(MB/s)
8GFC	8.5	8.5	800
16GFC	14.025	14.025	1600
32GFC	28.025	28.025	3200
64GFC	28.900	57.8	6400

- Important: Max datarate of FC interfaces is lower than the used notation
  - What's the % utilization of 25Gbps a on 32GFC port? (Wrong: 25/32 = 78%. Correct: 25/28 = 89%)
  - Use correct max bit-rate when DIYing link-utilization calculation or using 3rd party monitoring apps

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

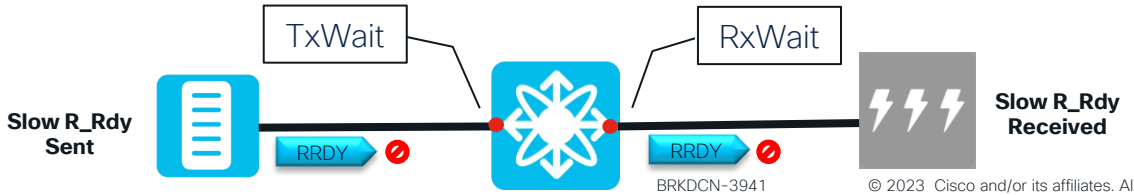
```
MDS9706-C# show logging onboard datarate
 ------------------------------------------------------------------------------------
| Interface |  Speed  |     Alarm-types              |    Rate    |         Timestamp        |
 ------------------------------------------------------------------------------------
|  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

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

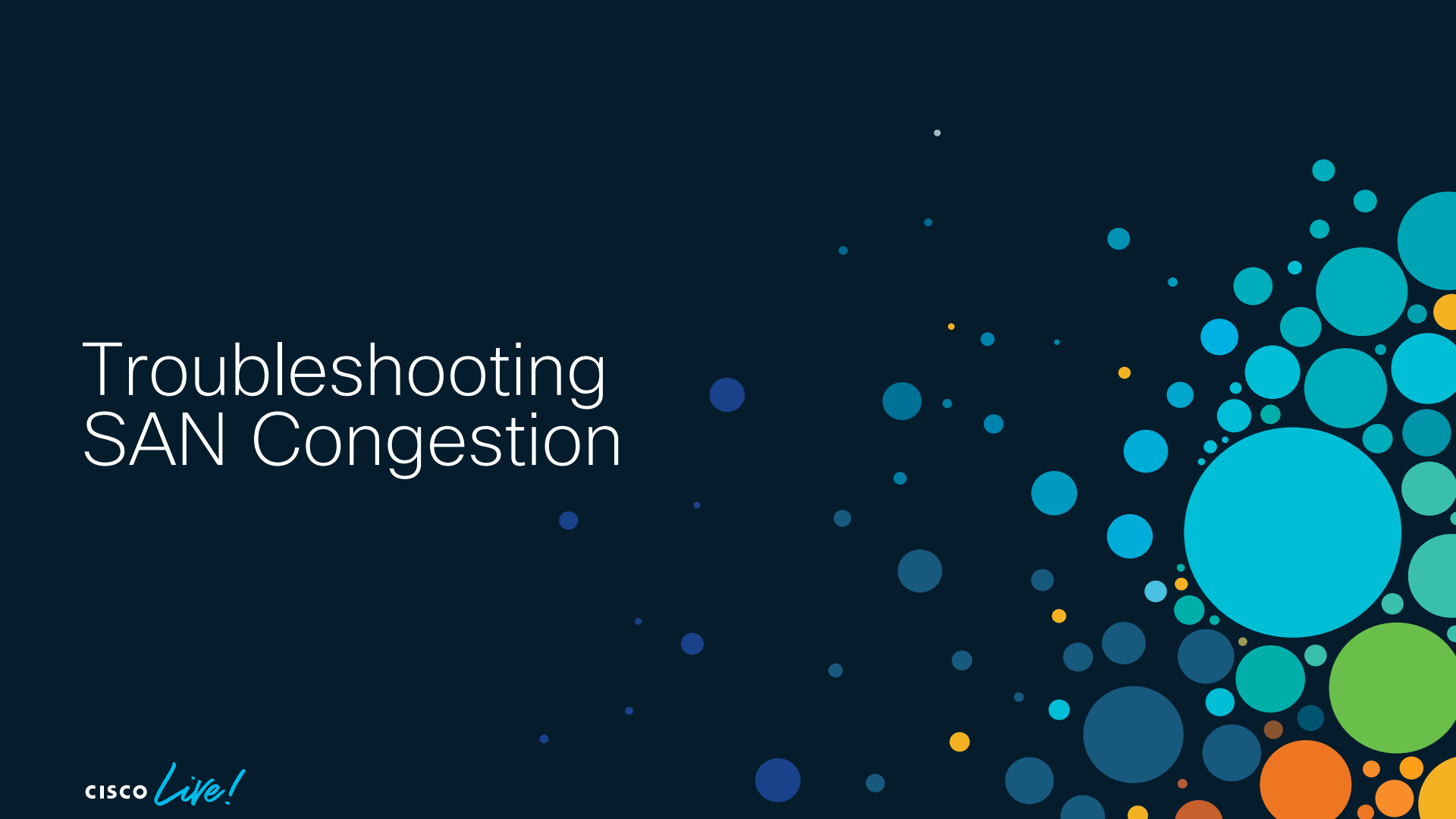
FCID of destination

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

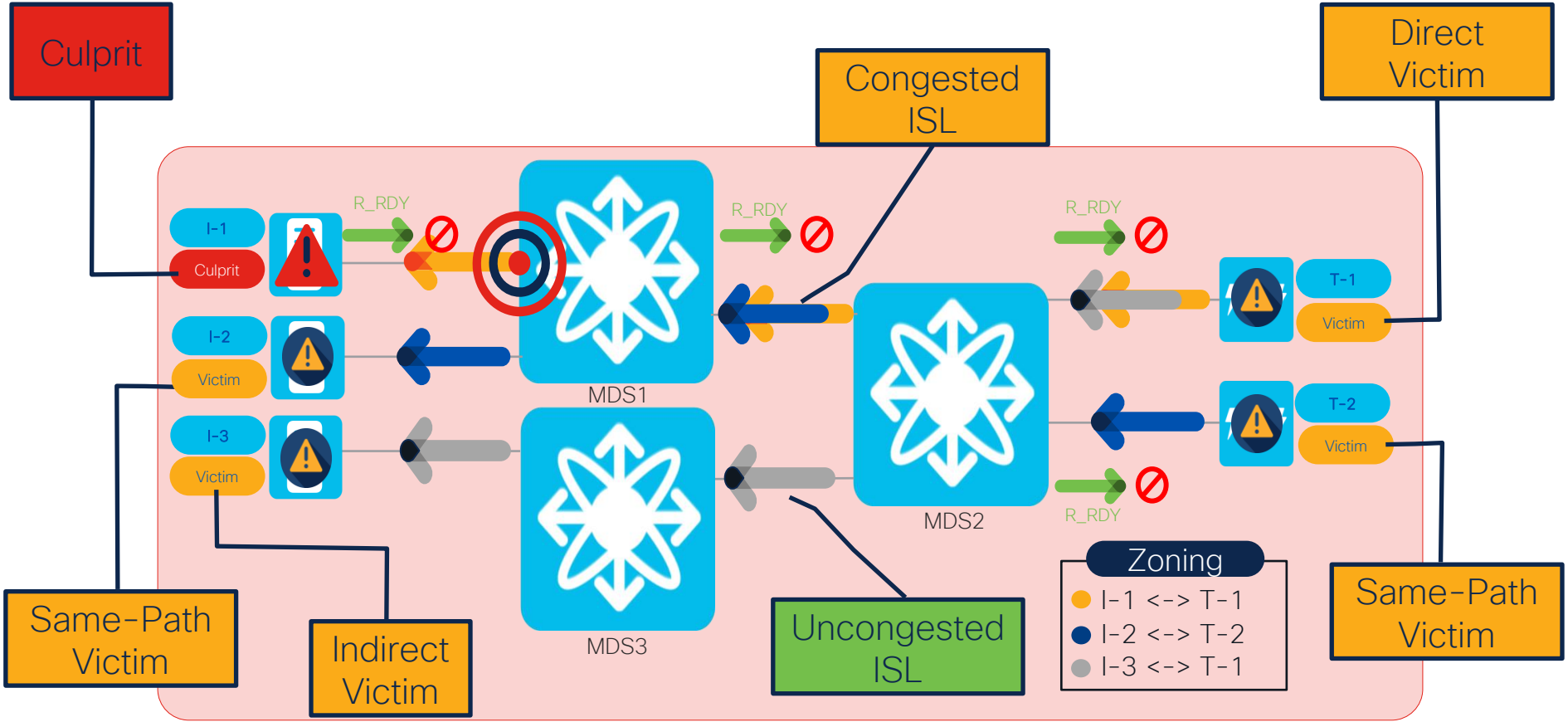
Culprits and Victims

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

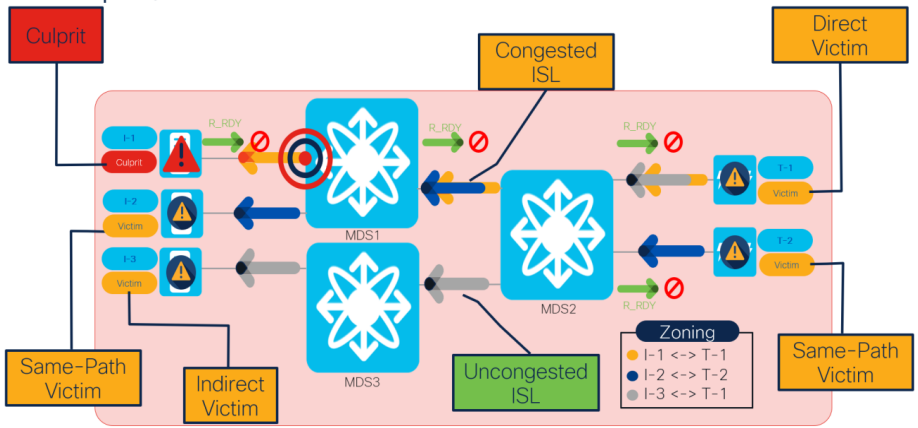
T-1 is Direct Victim

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)

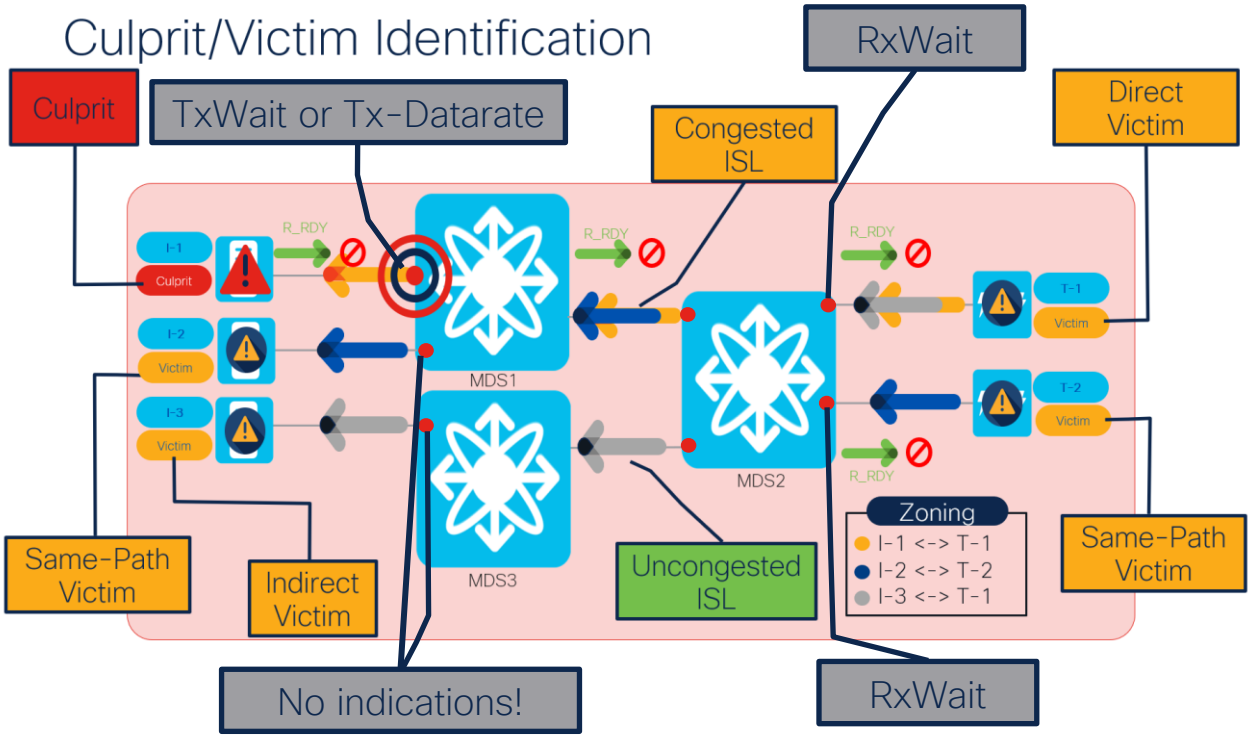
- All devices utilizing congested paths (e.g. All devices on MDS1) are potential ‘**Same-Path Victims**’

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

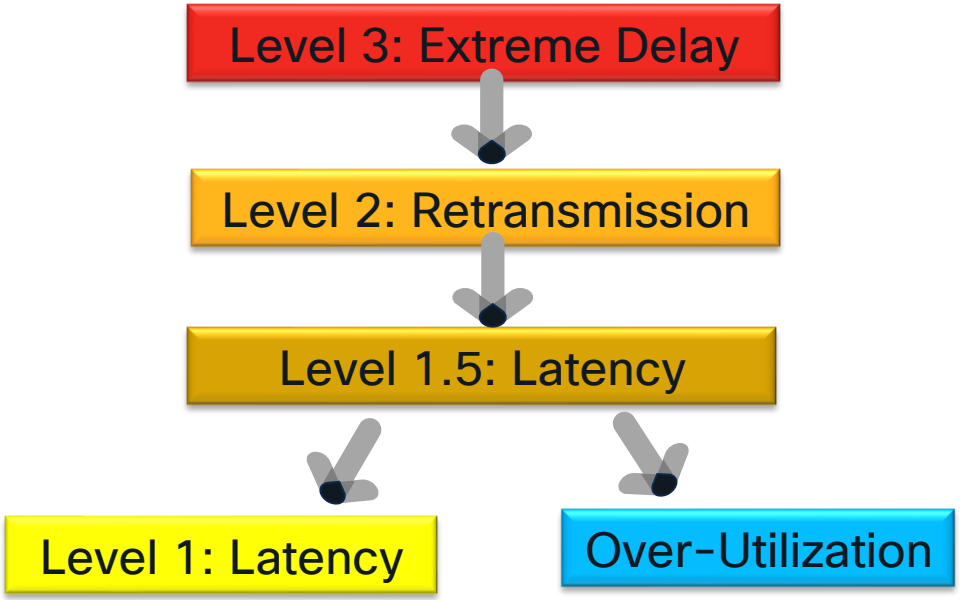
Level	Host Symptoms	Switch Behavior	Indications	Applicable Commands
1	Latency	Frame queuing	TxWait < 30% – Culprits, ISLs RxWait – Victims, ISLs	show interface <counters> show logging onboard txwait show logging onboard rxwait
1.5	Severe latency	Frame queuing	TxWait >= 30% – Culprits, ISLs RxWait – Victims, 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

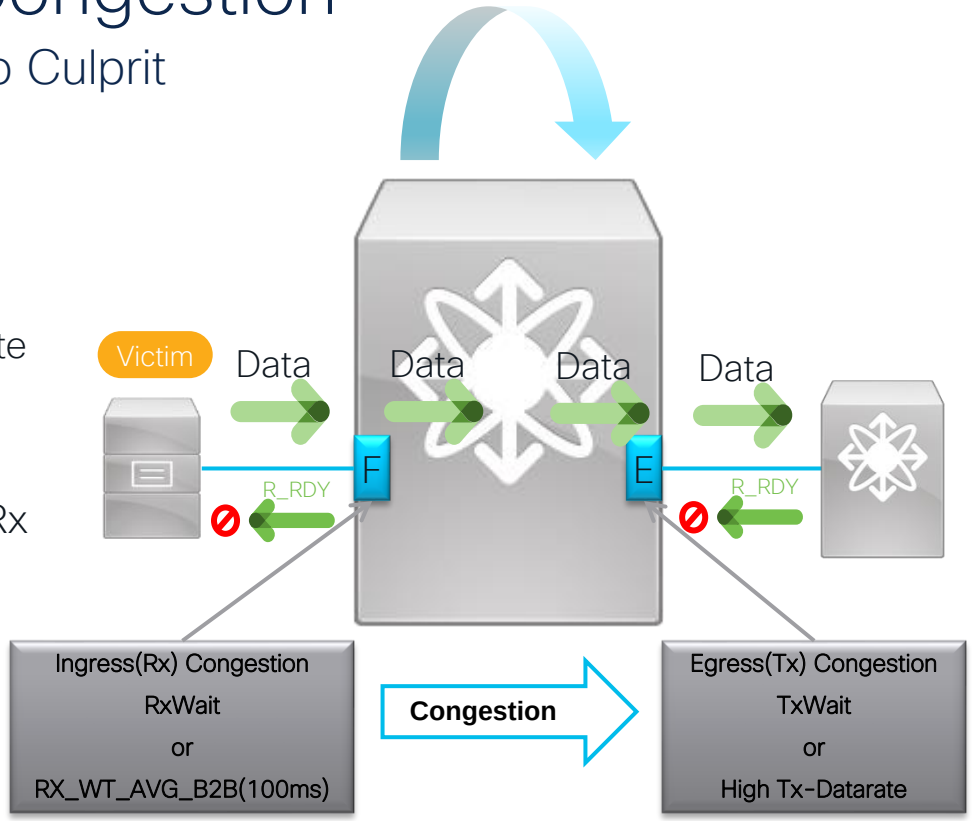
- Cisco recommends troubleshooting congestion in the following order:



Troubleshooting SAN Congestion

Methodology – Follow Congestion to Culprit

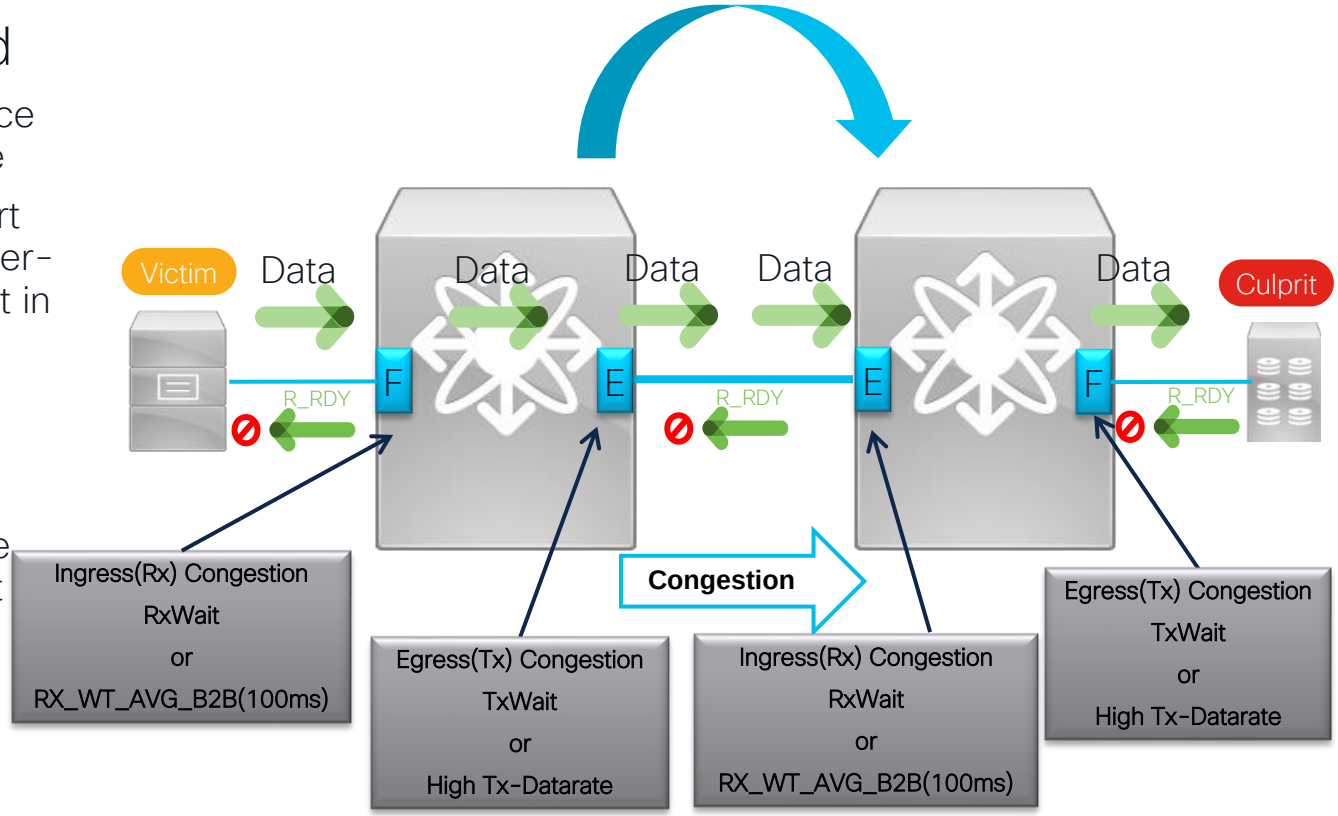
- If Rx congestion, then find ports communicating with this port that have Tx congestion
  - Zoning defines which devices communicate with this port
  - Understand topology
- If port communicating with port showing Rx congestion is FCIP
  - Check for TCP retransmits
  - Check for overutilization of FCIP



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 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

- 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 (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 – 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

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)

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

Troubleshooting SAN Congestion

Determining cause of level 3 congestion – Continued

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

Credit-loss-recovery on both fabric's 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 24 counters that can be monitored

Port-monitor has 10 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-count	**Monitor tx slow port sub-100ms 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
```

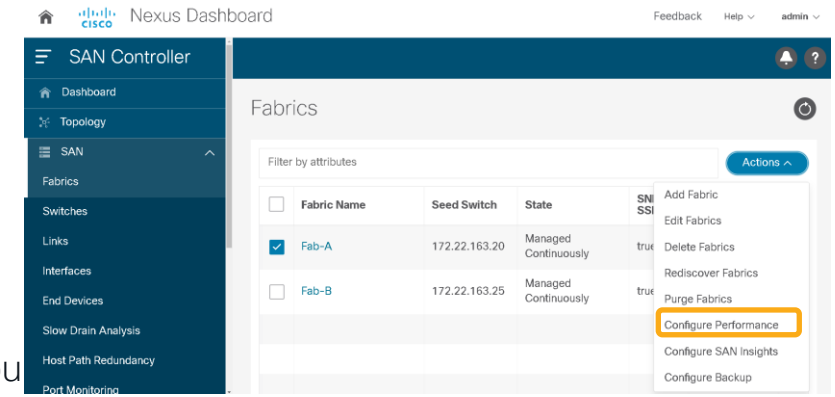
Counter	Threshold Type	Interval (Secs)	Warning		Thresholds		Rising/Falling actions			Congestion-signal	
			Threshold	Alerts	Rising	Falling	Event	Alerts	PortGuard	Warning	Alarm
Link Loss	Delta	30	none	n/a	5	1	4	syslog,rmon	FPIN	n/a	n/a
Sync Loss	Delta	30	none	n/a	5	1	4	syslog,rmon	FPIN	n/a	n/a
Signal 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.
```

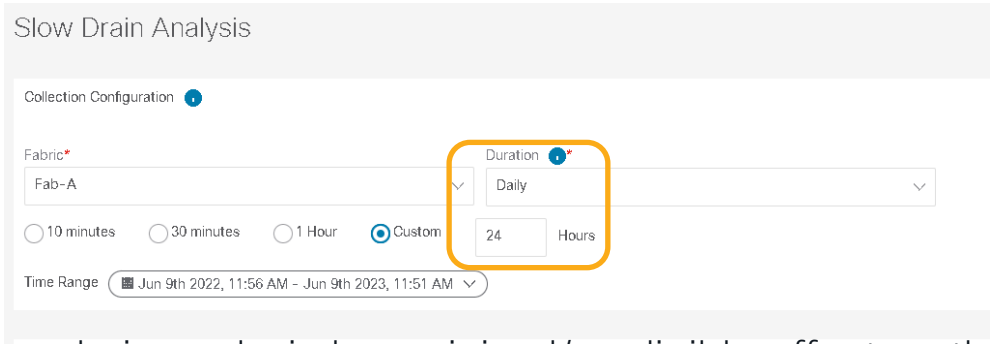
NDFC Congestion/Congestion Analysis

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



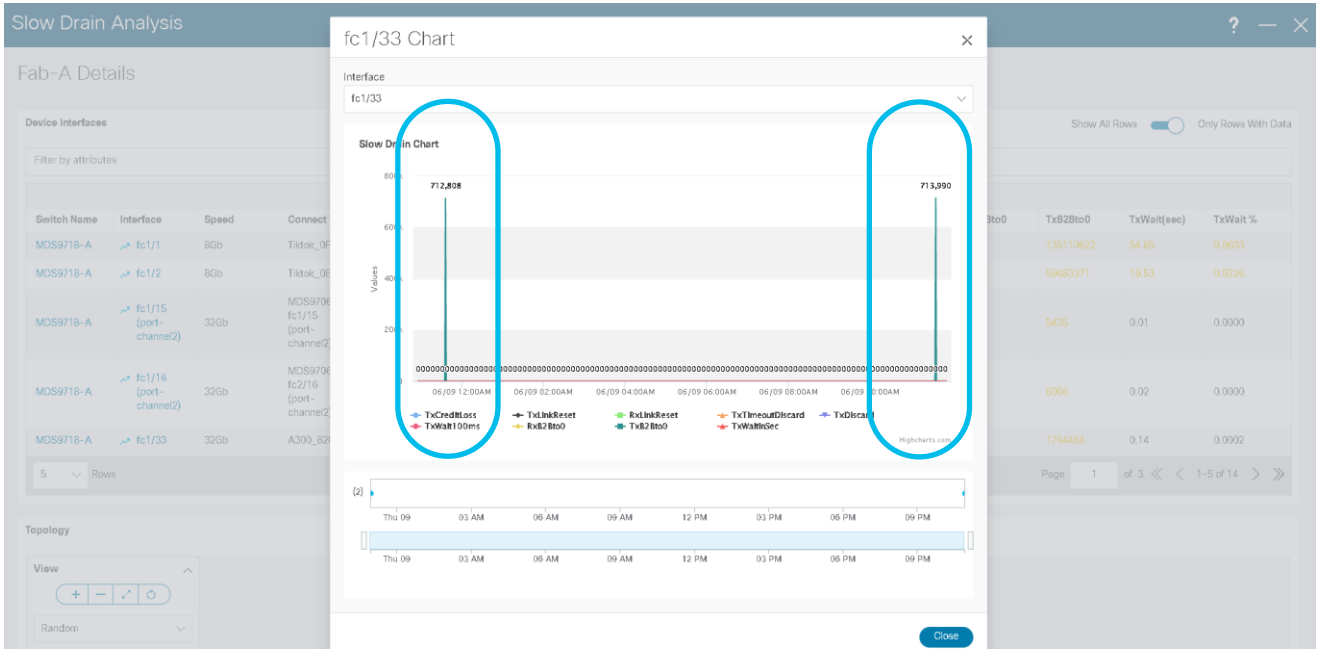
*Slow-drain Analysis is renamed to Congestion Analysis in NDFC 12.1.1e

- 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.

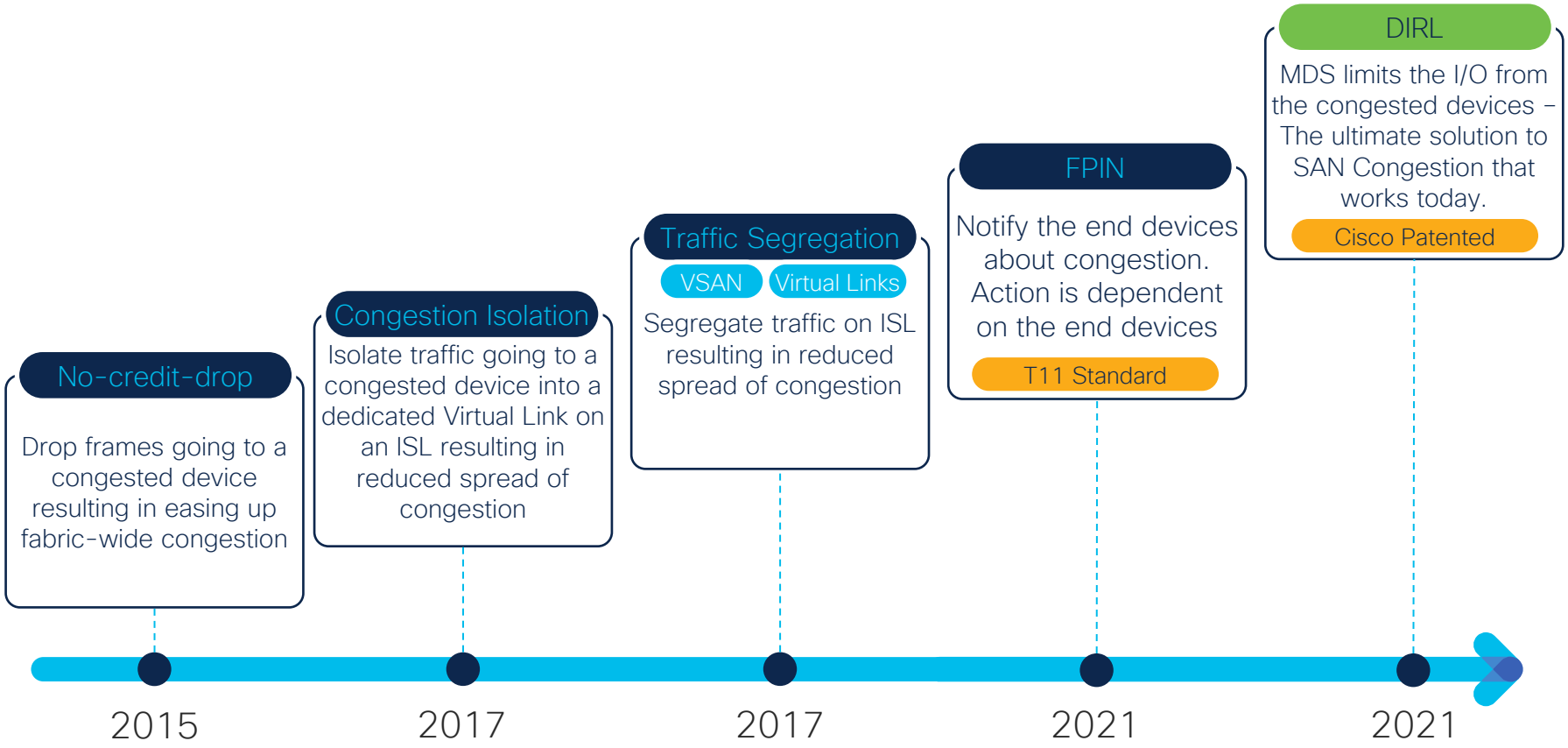


SAN Congestion

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



Not an exhaustive list

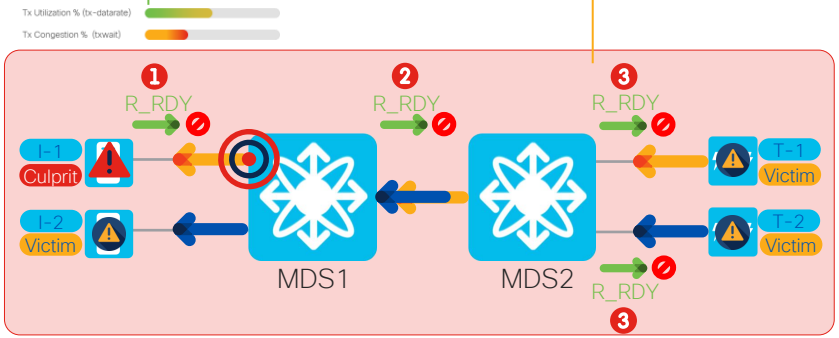
Common Causes of SAN Congestion

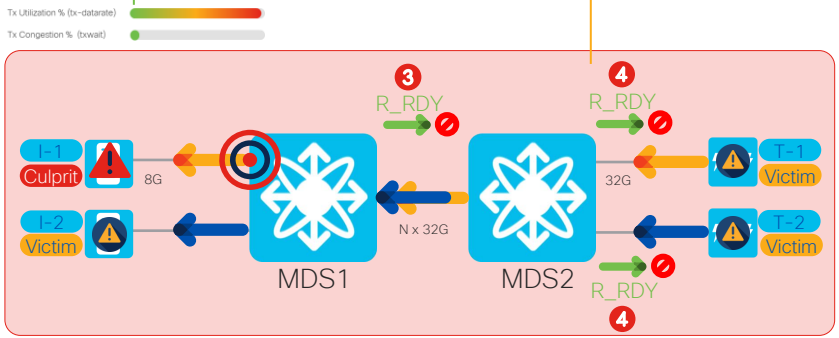
Slow Drain

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

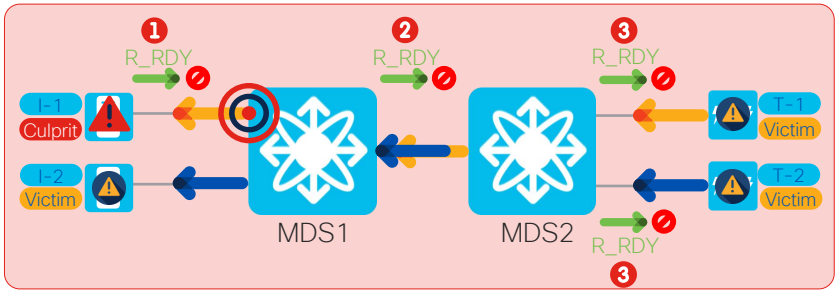
Slow Drain

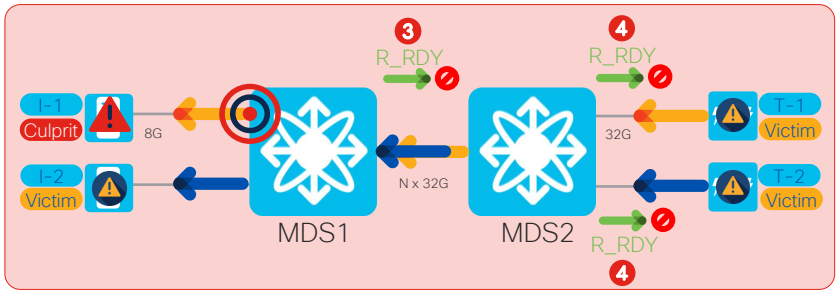
Over-Utilization

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

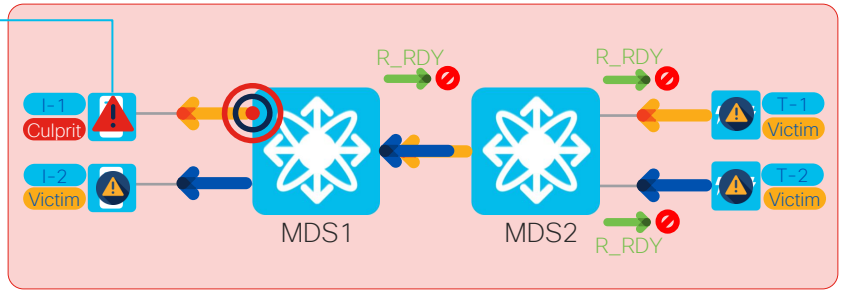




The Root Cause of SAN Congestion

The Root Cause

I-1 is receiving more than it can ingest



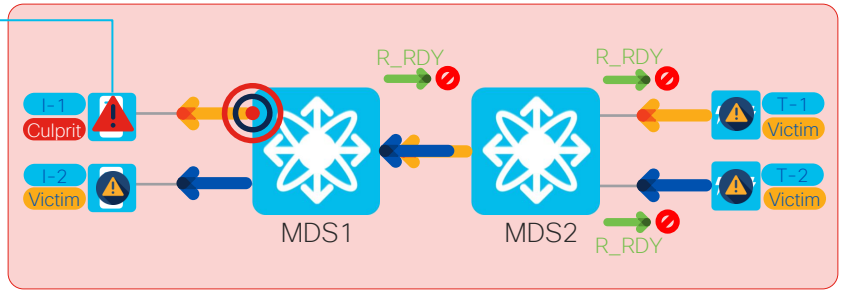
The Root Cause of SAN Congestion

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

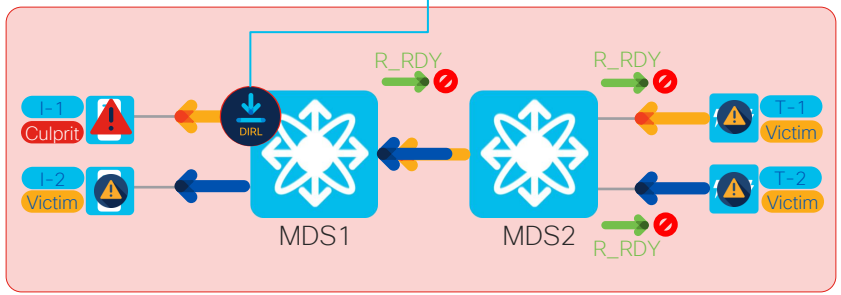
Cisco Dynamic Ingress Rate Limiting

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



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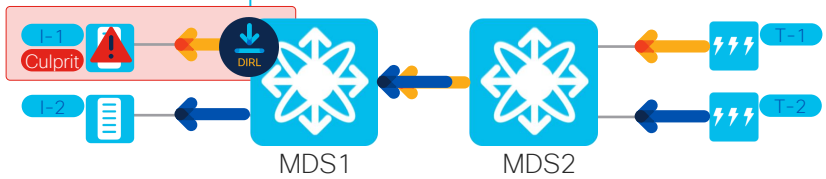
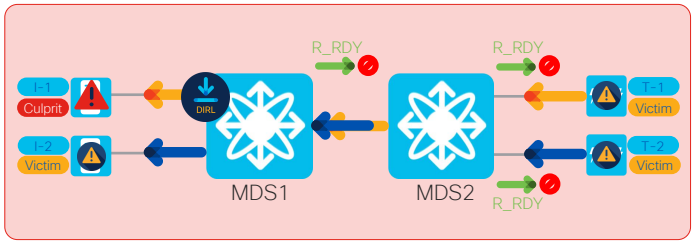


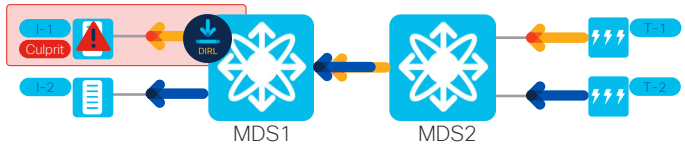
DIRL prevents SAN Congestion due to slow-drain **and** over-utilization.

Cisco Dynamic Ingress Rate Limiting

Without Cisco DIRL



With Cisco DIRL



Back pressure alleviated!

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

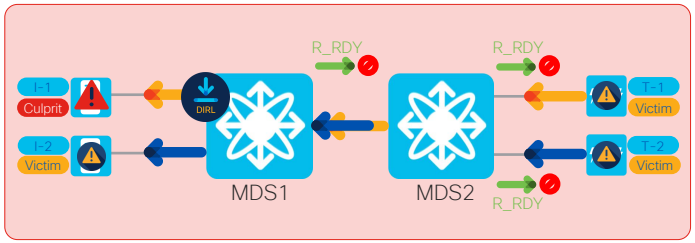
Easy adoption
DIRL is available on MDS switches after a software-only upgrade.

Gradual Rollout
DIRL can be implemented one switch at a time

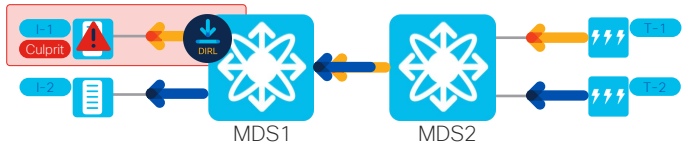
Affordable
No additional license needed

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

Without Cisco DIRL

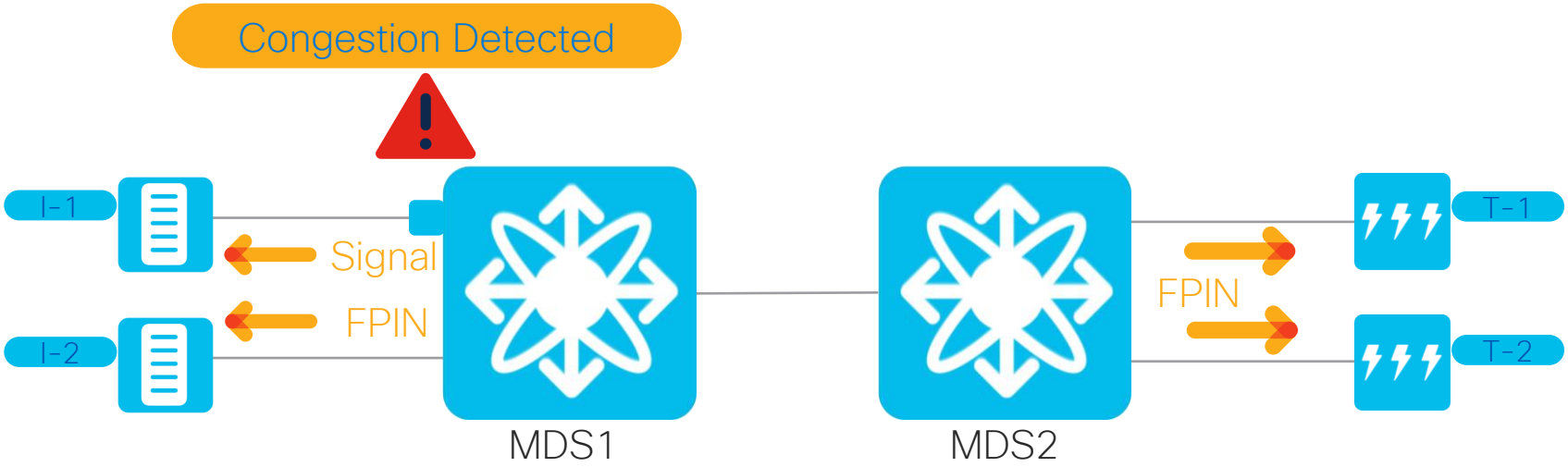


With Cisco DIRL



Back pressure alleviated!

Notifications and Congestion Signals in Fibre Channel

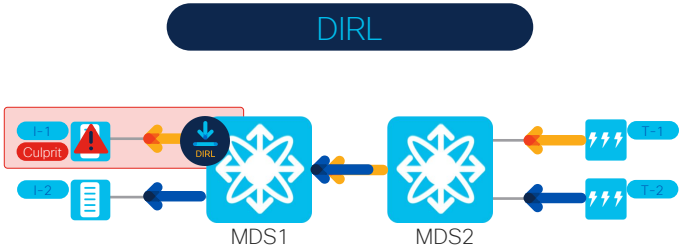


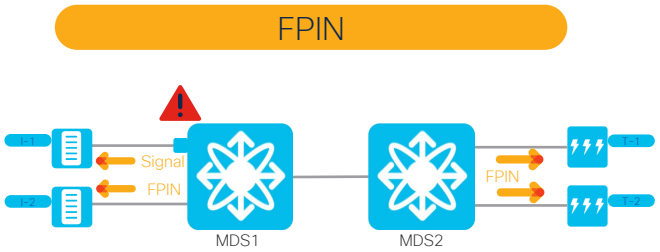
Available on Cisco MDS in NX-OS 8.5(1) onwards

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

- Schedule NDFC/DCNM Slow-drain Analysis to run daily for 24 hours.
- Important for troubleshooting
- Gather ‘show tech-support slowdrain’ from all switches

Proactive

- 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

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