# Performance Evaluation of the GSI timing network

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25.04.2025

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## 1. Overview

The objective of this test is to evaluate the performance of a timing network implemented on the White Rabbit switches (WRS). In addition to precise timing synchronization, the WR network ensures the reliable distribution of control data within a timing system. Therefore, it is essential to assess the timing network's performance with respect to standard qualification factors such as throughput and latency. These factors are evaluated in typical network traffic scenarios:

- Data Master (DM) broadcast: this is typical scenario, in which the control data is broadcast by a central DM node to all recipients within a network
- Bunch-2-Bucket (B2B) traffic (many-to-one): in this case, the control data is unicast from multiple B2B nodes to a single DM node
- mixed traffic (1 DM, 6 B2B, 9 service): the control data traffic (both DM and B2B) and the service data traffic are available within a network

Bandwidth is a measure of the data volume that can pass through a network at any given time. It's not a measure of speed but rather a reflection of capacity, dependent on both throughput and latency.

Throughput represents the average amount of data that actually traverses a network within a certain time period.

Network latency is the amount of time that takes for data to move from its source to a destination across a network.

## 2. Test setup

The testbed consists of the following components:

- chassis: XenaBay
- software: Xena2889 v1.46, XenaManager v1.96.8942.2 (Xena software release 98)
- configuration: https://github.com/GSI-CS-CO/network_testing/
  - GSI_Use_Case_test/performance_analysis_2025_4/Configuration/XenaManager_and_Xena2889/RFC_2889_4_switches_*.x2889
  - GSI_Use_Case_test/performance_analysis_2025_4/Configuration/XenaManager_and_Xena2889/xenabay_gsi_use_case_4_layers.xmcfg

The complete test setup is constructed using four 4 layers of WRS, each configured with its corresponding layer role (localmaster, distribution and access).
**Note**: timing_localmaster_xenabay, timing_access_all_xenabay, timing_access_mixed_xenabay are special configurations for the localmaster and access WRSs (in which RADIUS is disabled).

All WRSs, model WRS-3/18, are programmed with software release **v8.0**. Hardware versions of v3.3 and v3.4 are mixed within the test setup.

The XenaBay chassis serves as both the traffic generator and analyzer. Two application software are used: Xena2889, XenaManager
Using the Xena2889 software, advanced network tests can be performed according to the RFC 2889 specification. The provided throughput and forwarding rate tests are performed for individual traffic types (DM and B2B), and the maximum throughput is measured.

The XenaManager software is employed to generate a mix of different data traffic and measure their their frame loss. Measured results are evaluated manually.

**Note**: in case of trouble reboot the XenaBay chassis and restart the Xena software. Rebooting the chassis can be done by XenaManager (Available Resources:reserve chassis -> Resource Properties: reboot chassis).

For DM broadcast and B2B unicast traffics, the test frames simulate the timing messages, ranging from 1 to 16 messages per frame. The layer 2 frame length of 90 bytes corresponds to 1 timing message per frame (preamble (7 octets), start frame delimiter (SFD, 1 octet) and interpacket gap (IPG, 12 octets) are not considered).

The service traffic represents any network traffic with all possible frame lengths, ranging from 64 to 1518 bytes.

## 3. Test result records

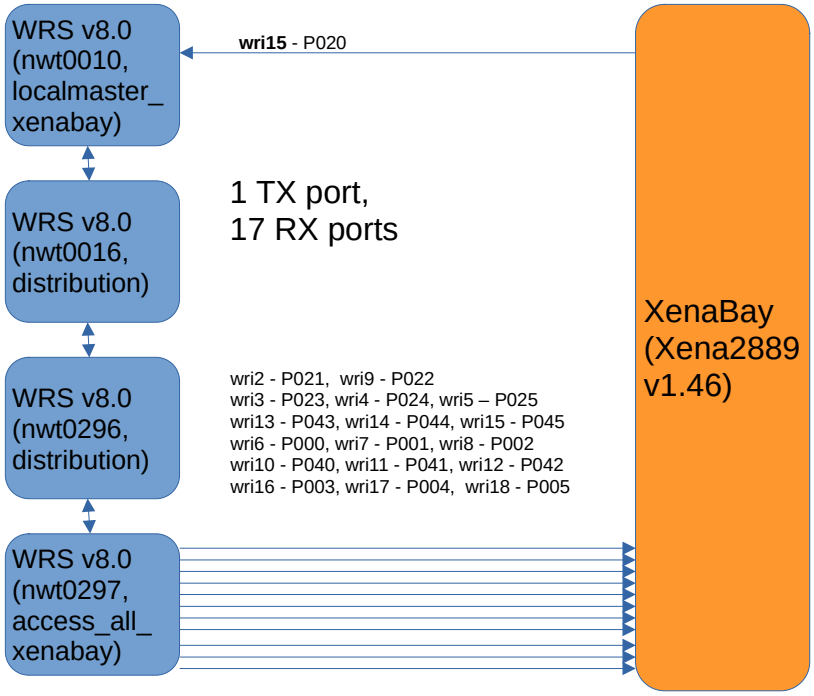
All test results are stored in separate files in the ‘Results’ folder:

- DM broadcast, 1-to-17:
  - xena2889-report_gsi_dm_broadcast_4_layers_v8-20250409-111603.pdf
- B2B traffic, 17-to-1:
  - xena2889-report_gsi_b2b_17_traffic_4_layers_v8-20250408-175045.pdf
- mixed traffic:
  - mixed_traffic/*.csv

Commands and scripts to parse the measurement values from a given report file:

- results of the RFC 2889 tests are recorded into the PDF files
  - convert PDF file to plain text file:
    - pdftotext -f 3 -l 6 -layout <xena2889-report.pdf>
  - parse ‘Latency’ values (e.g., for frame length of 90 bytes) from the plain text file and sort them:
    - for str in Avg Min Max; do echo $str; grep "$str Latency" <xena2889-report.txt> | tr -s ' ' | cut -d " " -f 5 | sort -g; done
- results of the mixed traffic tests are recorded into CSV files
  - parse the measurement values (TX/RX packets, latency) from the mixed traffic test
    - mixed_traffic/parse.sh

### 3.1. DM Broadcast Forwarding Results




Throughput and latency for the DM broadcast were measured using the RFC 2889 broadcast forwarding test (fraction=100%, duration=30 seconds, iteration=3, TX rate: initial=0,1%, max=100%, min=0,01%, resolution=1%)[1].

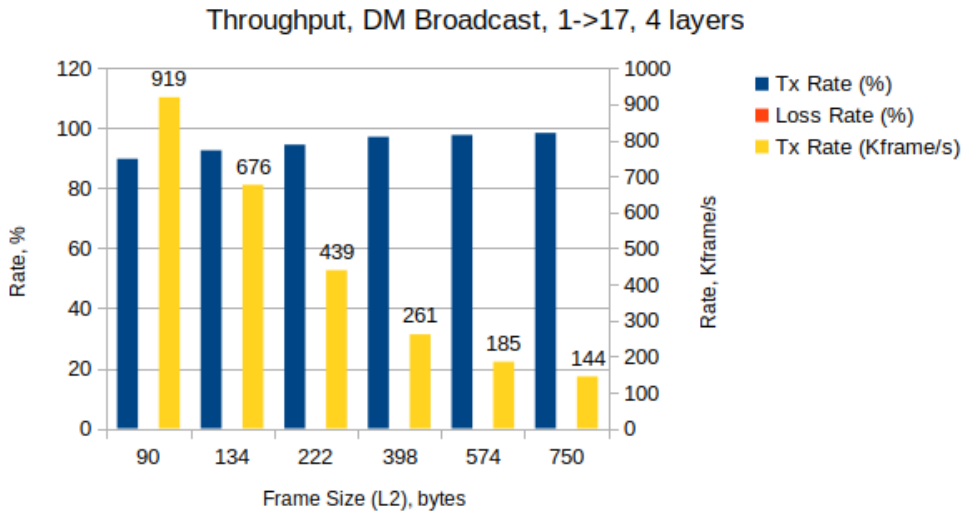
#### Throughput

Timing message broadcast (frame length = 90-750 bytes) was generated from 1 source port reserved for DM (nwt0010:wri15) and received at 17 destination ports (nwt0297). The measurements show that a single timing message could be broadcast up to 89,8% (corresponds to 808,7 Mb/s or 919 Kframe/s) of the total data rate of the WR switch. Additionally, the throughput slightly increased to 98,4% (886,2 Mb/s or 144 Kframe/s) when multiple timing messages (eg., 16 messages) were sent per frame.
Comparison to the previous test for v7.0 the measured values **remain unchanged**.

| **Timing messages** | 1 | 2 | 4 | 8 | 12 | 16 |
|---|---|---|---|---|---|---|
| **Frame size (L2, excl. preamble, SFD, IPG), bytes** | 90 | 134 | 222 | 398 | 574 | 750 |
| **TX rate, %** | 89,8 | 92,6 | 94,5 | 97,1 | 97,7 | 98,4 |
| **TX rate, Kframe/s** | 919 | 676 | 439 | 261 | 185 | 144 |
| **Loss, frames** | 0 | 0 | 0 | 0 | 0 | 0 |

Table 3.1.a. DM broadcast throughput

1 xena2889-report_gsi_dm_broadcast_4_layers_v8-20250409-111603.pdf



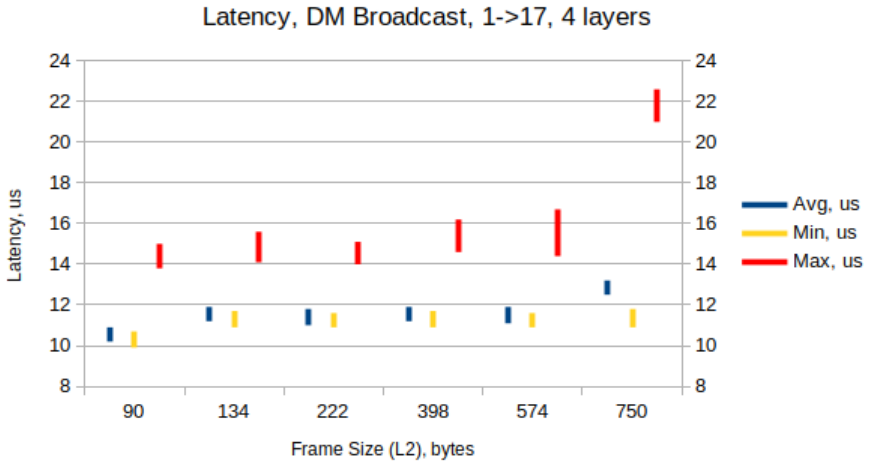

### Latency and Jitter

The measured values remain **almost unchanged** in comparison to the previous test for v7.0.

The average latency was reported to be around 10,2 to 10,9 us. Here, low and high values are boundary values from all ports. The difference of around 1-2 us was measured between broadcasting of a single timing message and (a few) multiple timing messages in a frame. The minimum and maximum latencies ranged from 9,9 to 11,8 us, and from 13,8 to 22,6 us, respectively.

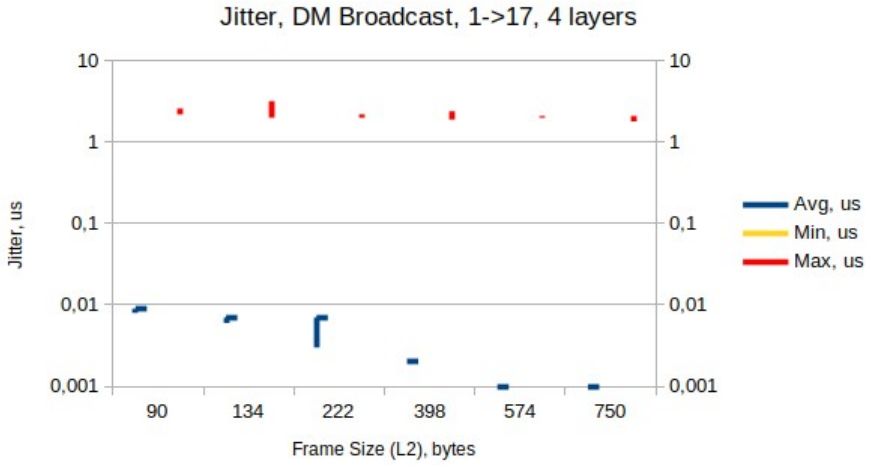
| **Timing messages** | 1 | 2 | 4 | 8 | 12 | 16 |
|---|---|---|---|---|---|---|
| **Frame size (L2), bytes** | 90 | 134 | 222 | 398 | 574 | 750 |
| **Avg (low), us** | 10,2 | 11,2 | 11 | 11,2 | 11,1 | 12,5 |
| **Avg (high), us** | 10,9 | 11,9 | 11,8 | 11,9 | 11,9 | 13,2 |
| **Min (low), us** | 9,9 | 10,9 | 10,9 | 10,9 | 10,9 | 10,9 |
| **Min (high), us** | 10,7 | 11,7 | 11,6 | 11,7 | 11,6 | 11,8 |
| **Max (low), us** | 13,8 | 14,1 | 14 | 14,6 | 14,4 | 21 |
| **Max (high), us** | 15 | 15,6 | 15,1 | 16,2 | 16,7 | 22,6 |

Table 3.1.b. Latency in the DM broadcast

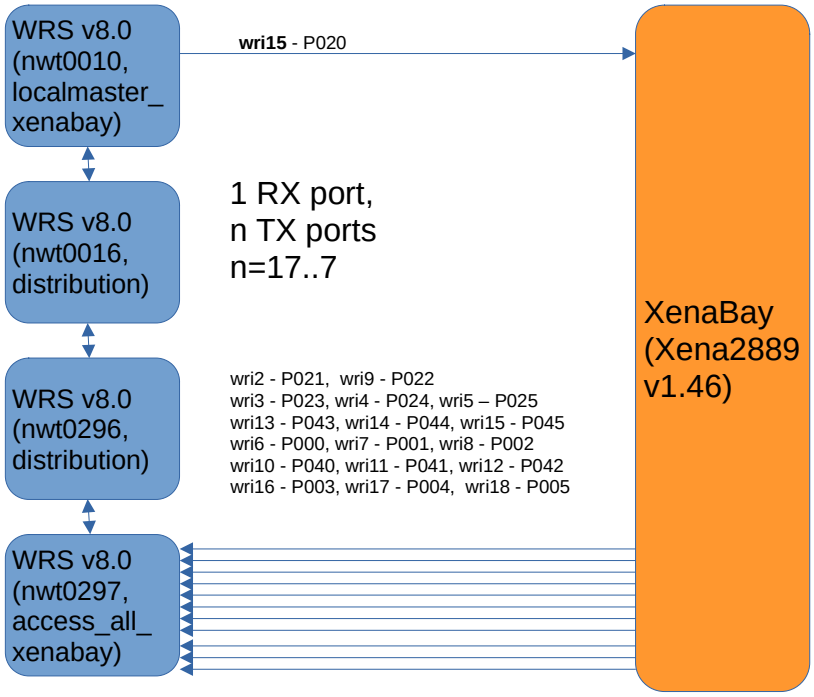


| Timing messages | 1 | 2 | 4 | 8 | 12 | 16 |
|---|---|---|---|---|---|---|
| Frame size (L2), bytes | 90 | 134 | 222 | 398 | 574 | 750 |
| Avg (low), us | 0,008 | 0,006 | 0,003 | 0,002 | 0,001 | 0,001 |
| Avg (high), us | 0,009 | 0,007 | 0,007 | 0,002 | 0,001 | 0,001 |
| Min (low), us | 0 | 0 | 0 | 0 | 0 | 0 |
| Min (high), us | 0 | 0 | 0 | 0 | 0 | 0 |
| Max (low), us | 2,2 | 2 | 2 | 1,9 | 2 | 1,8 |
| Max (high), us | 2,6 | 3,2 | 2,2 | 2,4 | 2,1 | 2,1 |

Table 3.1.b. Jitter in the DM broadcast



### 3.2. B2B Traffic Forwarding Results




Throughput was measured using the RFC 2889 1:n partial mesh test (overall test port rate=1% (L1 9Mb/s), duration=30 seconds, iteration=3, topology=blocks, direction=west-to-east, TX rate: initial=1%, min=0,01%, max=100%, res=0,1%). In general, the B2B traffic is generated at 17 west ports (nwt0297) and forwarded to 1 east port (nwt0010). Network throughput was measured depending on number of timing messages in a frame (frame length = 90-750 bytes), and number of west ports (n).

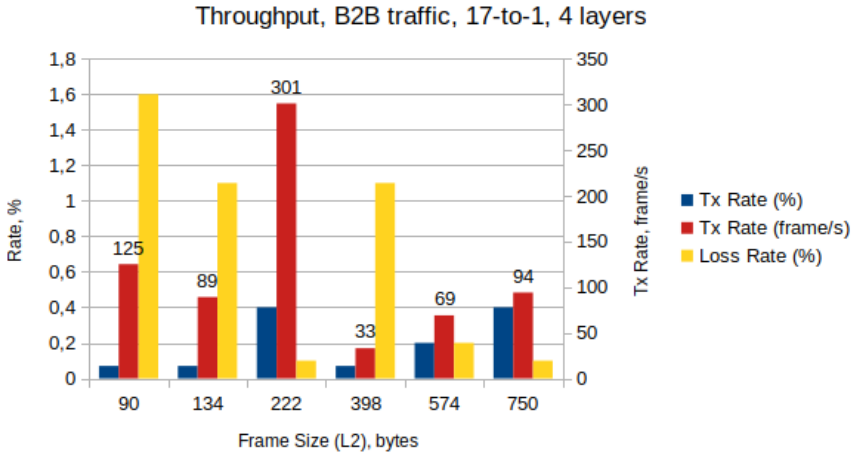
#### Throughput, 17 TX ports[2]

There are frame losses for all frame lengths.
Comparison to the previous test for v7.0 shows **little difference:** frame loss rate is slightly higher for SW v8.0 (1,6% vs 1,1% at most).

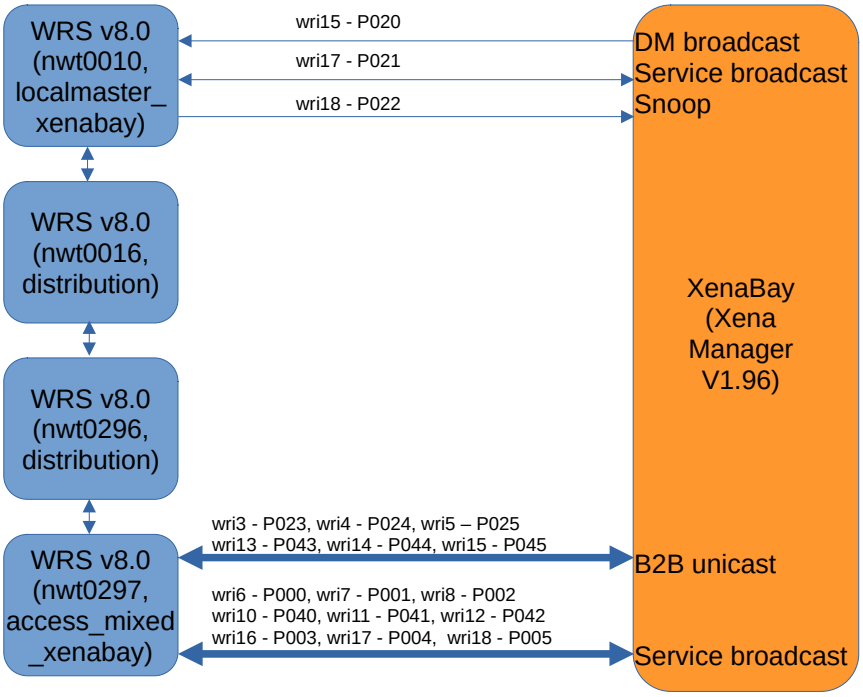
| **Timing messages** | 1 | 2 | 4 | 8 | 12 | 16 |
|---|---|---|---|---|---|---|
| **Frame size (L2), bytes** | 90 | 134 | 222 | 398 | 574 | 750 |
| **Tx Rate (%)** | 0,07 | 0,07 | 0,4 | 0,07 | 0,2 | 0,4 |
| **Tx Rate (frame/s)** | 125 | 89 | 301 | 33 | 69 | 94 |
| **Tx Rate (Kb/s)** | 109,7 | 109,6 | 583 | 110 | 328,5 | 581,8 |
| **Result** | Fail | Fail | Fail | Fail | Fail | Fail |
| **Loss Frames** | 60 | 29 | 9 | 11 | 5 | 3 |
| **Loss Rate (%)** | 1,6 | 1,1 | 0,1 | 1,1 | 0,2 | 0,1 |

Table 3.2. B2B traffic throughput

2 xena2889-report_gsi_b2b_17_traffic_4_layers_v8-20250408-175045.pdf


Throughput, B2B traffic, 17-to-1, 4 layers
Rate, %
Tx Rate, frame/s
Frame Size (L2), bytes
90
134
222
398
574
750
125
89
301
33
69
94
Tx Rate (%)
Tx Rate (frame/s)
Loss Rate (%)

### 3.3. Mixed Traffic Test Results




The DM broadcast, B2B unicast, and service broadcast traffics are generated with different data rate and frame length according to table below. The frame rate and length of the DM and B2B traffics are used as iteration parameters for each measurement. Each run takes 5 minutes. The service broadcast traffic is generated with data rate of 142 Kb/s and frame length of 64-1518 bytes for all measurements.
**Note**: all measurements are done by using XenaManager software. Load 'xenabay_gsi_use_case_4_layers.xmcfg'. Reserve all test ports (incl. P022 for snooping) and load corresponding port configurations.

| Layer | WRS port | XenaBay port | Data rate, Mb/s | Frame size, bytes (Frame rate, Kframe/s) | Traffic |
|---|---|---|---|---|---|
| 1 | LM:wri15 | P020 | 2, 10, 20, 50, 100 | 90, 134 (113,64, 81,17) | DM |
| | LM:wri17 | P021 | 0,14 | 64-1518 (21) | Service trunk |
| | LM:wri18 | P022 | | | (snooping) |
| 4 | A:wri3 | P023 | 2, 4, 8, 16, 32 | 90, 134 (4,54, 3,25) | B2B |
| | A:wri4 | P024 | 2, 4, 8, 16, 32 | 90, 134 | B2B |
| | A:wri5 | P025 | 2, 4, 8, 16, 32 | 90, 134 | B2B |
| | A:wri6 | P000 | 0,14 | 64-1518 | Service |
| | A:wri7 | P001 | 0,14 | 64-1518 | Service |
| | A:wri8 | P002 | 0,14 | 64-1518 | Service |
| | A:wri10 | P040 | 0,14 | 64-1518 | Service |
| | A:wri11 | P041 | 0,14 | 64-1518 | Service |
| | A:wri12 | P042 | 0,14 | 64-1518 | Service |
| | A:wri13 | P043 | 2, 4, 8, 16, 32 | 90, 134 | B2B |

| | | | | | |
|---|---|---|---|---|---|
| | A:wri14 | P044 | 2, 4, 8, 16, 32 | 90, 134 | B2B |
| | A:wri15 | P045 | 2, 4, 8, 16, 32 | 90, 134 | B2B |
| | A:wri16 | P003 | 0,14 | 64-1518 | Service |
| | A:wri17 | P004 | 0,14 | 64-1518 | Service |
| | A:wri18 | P005 | 0,14 | 64-1518 | Service |

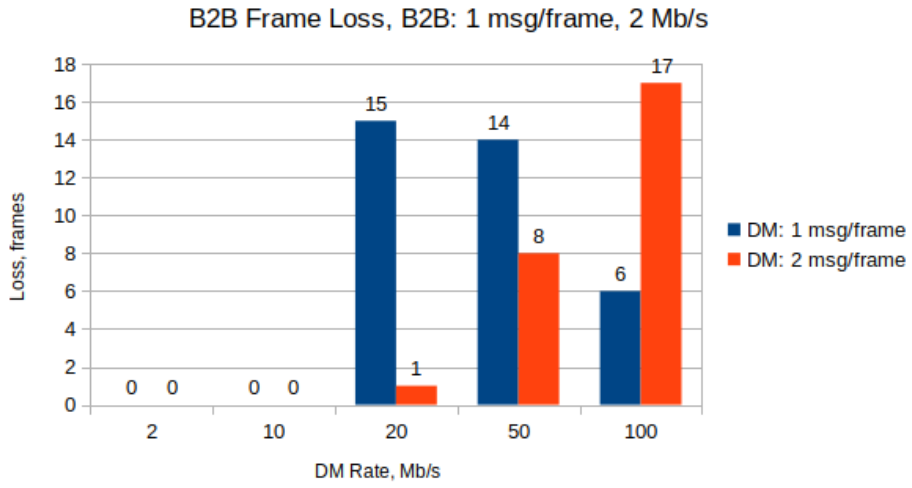
Table 3.3.a. Mixed traffic generation by XenaManager

### DM Frame Loss

No frame loss in the DM broadcast was detected within probed data rates from 2Mb/s to 100 Mb/s, and frame length of 90 and 134 bytes. Data rate and frame length for the B2B traffic are at 2Mb/s and 90 bytes (1 msg/frame).

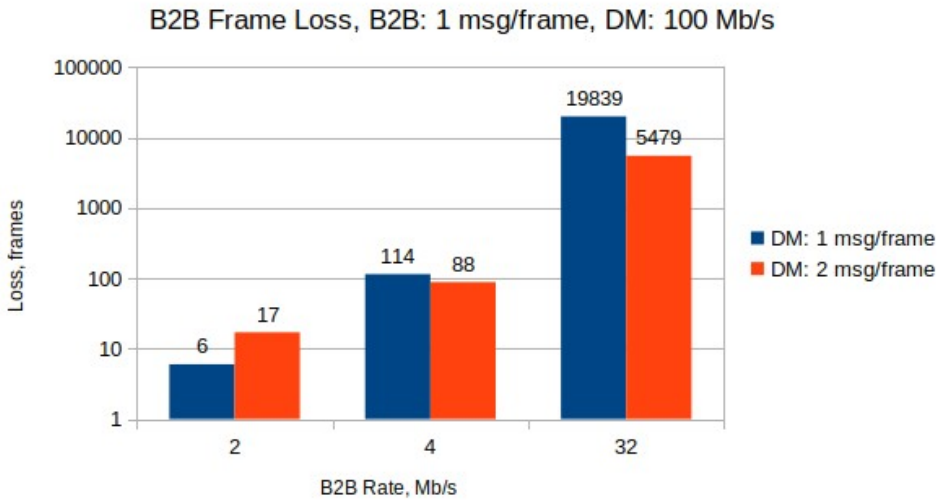
### B2B Frame Loss

Frame loss in the B2B traffic was detected in higher data rates of the DM and B2B traffic:




| **DM rate, Mb/s** | | 10 | 20 | 50 | 100 |
|---|---|---|---|---|---|
| **DM rate, frame/s** | | 11636 | 22727 | 56818 | 113636 |
| **B2B frame loss, frames** | DM msg/frame = 1 (90 bytes) | 0 | 15 | 14 | 6 |
| | DM msg/frame = 2 (134 bytes) | 0 | 1 | 8 | 17 |
| **B2B frame loss rate** | DM msg/frame = 1 | 0 | $2{,}2*10^{-5}$ | $2*10^{-5}$ | $8{,}8*10^{-6}$ |
| | DM msg/frame = 2 | 0 | $1{,}5*10^{-6}$ | $1{,}2*10^{-5}$ | $2{,}5*10^{-5}$ |

Table 3.3.b. B2B frame loss (depending on the DM frame rate and size)




| **B2B rate, Mb/s** | | 2 | 4 | 32 |
|---|---|---|---|---|
| **B2B rate, frame/s** | | 2272 | 4545 | 36363 |
| **B2B frame loss, frames** | DM msg/frame = 1 (90 bytes) | 6 | 114 | 19839 |
| | DM msg/frame = 2 (134 bytes) | 17 | 88 | 5479 |
| **B2B frame loss rate** | DM msg/frame = 1 | $8{,}8*10^{-6}$ | $8{,}3*10^{-5}$ | $1{,}8*10^{-3}$ |
| | DM msg/frame = 2 | $2{,}5*10^{-5}$ | $6{,}4*10^{-5}$ | $1{,}8*10^{-3}$ |

Table 3.3.c. B2B frame loss (depending on the B2B frame rate and DM frame size)

In addition, the frame loss was detected only with B2B frames that has the length of 1 timing message. For other frame lengths (2/4/8 timing messages) **no** frame loss was detected (DM rate=100Mb/s, 1 msg/frame).

| **B2B frame** | **B2B frame size, bytes** | **B2B frame loss** |
|---|---|---|
| 1 message/frame | 90 | detected |
| 2, 4, 8 messages/frame | 134, 222, 398 | not detected |

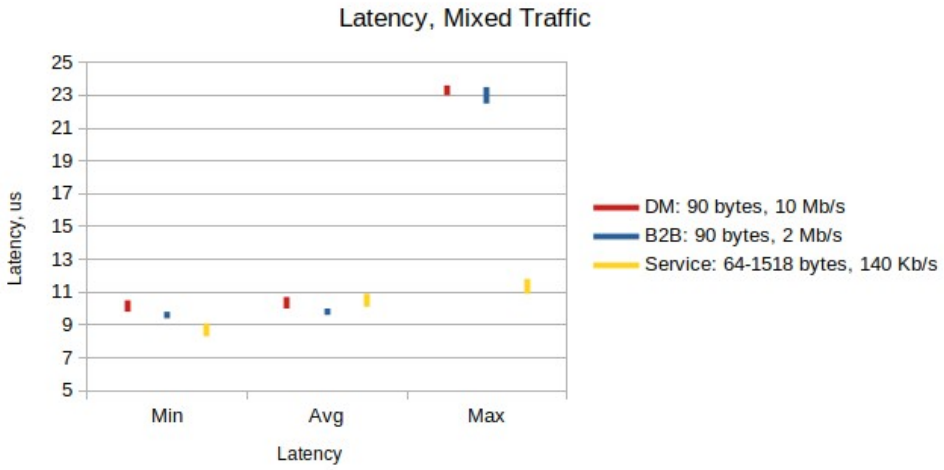
Table 3.3.d. B2B frame loss (depending on the B2B frame size)

### Service Frame Loss

According the network configuration there are two uni-directional service traffic is enabled: upstream (layer 4 to layer 1) and downstream (layer 1 to layer 4). Frame loss occurred in the downstream traffic at rate of $1{,}85*10^{-3}$ (e.g., 204 lost frames out of ~110K TX frames).

### Latency

Latency is not evaluated for all measurements, but a single case measurement (DM: 10Mb/s, 90 bytes, B2B: 2Mb/s, 90 bytes) shows that the average latency lays between 9,6 and 10,9 us for all traffic types. The maximum latency around 23 us was measured for the DM broadcast and B2B traffics.




| Traffic types | Min latency, us | Avg latency, us | Max latency, us |
|---|---|---|---|
| DM: 90 bytes, 10 Mb/s | 9,8-10,5 | 10-10,7 | 23-23,6 |
| B2B: 90 bytes, 2 Mb/s | 9,4-9,8 | 9,6-10 | 22,5-23,5 |
| Service: 64-1518 bytes, 140 Kb/S | 8,3-9,1 | 10,1-10,9 | 10,9-11,8 |

Table 3.3.e. Latency of all traffic (DM: 10Mb/s, 90 bytes, B2B: 2Mb/s, 90 bytes)

## 4. Conclusion

In general, the software release v8.0 fulfills the key requirements for the GSI/FAIR Timing System (WR network with 4 layers):

- propagation time of a few hundred us through network: average and maximum latency range from **13,2 us up to 22,6 us**
- robustness: at least **no frame loss for 27M** control frames (frame loss should be less than 10e-12). As of writing, the production localmaster WRS has the RX frame count of 56M and 487M frames for the DM ports (wri15/16) in 158 days.

These measured values for network latency and throughput are in the **same range** as the previous measurements for v7.0.