Performance Evaluation of
the White Rabbit switch
(RFC 2889 Benchmarking)

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1. Overview

The performance of the White Rabbit switch is evaluated by the methods defined in RFC 2889. This RFC deals with networking devices at the Medium Access Control (MAC) layer and provides a methodology for checking the capabilities given below:
- frame forwarding performance (forwarding rate and throughput)
- congestion control
- forward pressure and maximum forwarding rate
- broadcast forwarding and latency
- address handling

The testbed includes:
- chassis: XenaBay
- software: Xena2889 **v1.46** (former Valkyrie2889), Windows 10 Enterprise LTSC 2021
- configuration: https://github.com/GSI-CS-CO/network_testing
    - wr_RFC_2889/xena_cfg/RFC_2889_1_switch_Xena.x2889

As a device under test the WR switch from Creotech (model WRS-3/18) with the HW version v3.4 and SW version **v8.0** is chosen.

Unlike to previous tests, RFC2889 benchmarking is done in one test setup:
- single WR switch

Similar to the all previous tests for SW versions v6.1 and v7.0, the test results are color coded to indicate if the WR switch **passes** or **fails** each test. The results that cannot be concluded are in **orange.**

Moreover, test results are compared with the results of previous test with **v7.0** and comparison results are coded as follows: better than previous (**+**), worse than (**-**) and not much different (**=**).

1 WR switch

Test results in 'wr_RFC_2889/xena_results/v8.0/xena2889-report_1_wrs_v80-20250408-091455.pdf' are evaluated.

- Traffic test(-): for all predefined frame lengths (64-1518 bytes) and bandwidths (10-100%, 100M-1Gb/s) there are frame losses. Throughput cannot be determined for all frame lengths in a single test. Test results show that total throughput (-) is **worsened** and the forwarding rates (=) **remain** similar compared to the v7.0 results.
  - full mesh (-): maximum total throughput reached to 12,9Mb/s (5,85Kframe/s) for the frame size 256 bytes. For a single port it corresponds to 0,7Mb/s (325 frame/s) data rate. The throughput tests were passed for the frame sizes of 64 and 256 bytes.
  - partial 1:N mesh (-): maximum total throughput reached to 3,2Mb/s with losses for all specified frame sizes. The throughput tests were failed for all specified frame sizes.

- - partial N:N mesh (-): maximum total throughput reached to 1,6Mb/s with losses for all specified frame sizes. The throughput tests were failed for all specified frame sizes.
- Congestion control (-): no congestion control. Neither 'head of line blocking' (for uncongested port) nor back pressure (for congested port) is detected. Frame loss of 62,8% is detected for the frame size of 1518 bytes.
- Forward pressure (=): no 'forward pressure' is detected and switch can guarantee the interfame gap (IFG) of 96-bits.
- Maximum forwarding rate (=): maximum TX rates of 90% to 100% are achieved. Frame losses are detected for the frame sizes of 64 and 1280 bytes.
- Address caching capacity and learning rate (=): switch has inherently the slow address learning capability (< 1ms). Therefore, at the relative low frame rate (20f/s) the switch can learn up to 1074 MAC addresses (and it starts flooding with more MAC addresses). There is a problem in MAC aging: switch keeps MAC addresses beyond the aging time. This means that if 'aging time' (or 'toggling sync state') is selected for address reset condition, then test is failed. This behavior is observed in all previous software versions including v4.2, v5.0.1, v6.0, v6.1 and v7.0.
- Errored frames filtering (=): oversized and undersized frames cannot be filtered, but invalid FCS frames.
- Broadcast forwarding (=): forwarding rates of 66% (663 Mb/s) to 94,4% (943,7 Mb/s) are measured. The longer the frame size => better the broadcasting rate. For all frame sizes except 512 bytes, the average latencies stay below 7 us. Only for the frame size of 512 bytes, the average and maximum latencies reached up to 121 us and 240 us, respectively, which are significantly higher than all other measurement results.

One-line commands to extract test results from a given report file:
- extract specific test results from a given PDF file and store them in plain text (eg., full mesh):
  - pdftotext -f 8 -l 57 -layout <xena2889-report.pdf>
- extract 'Rx Rate (Percent)' values (eg., for frame size of 64 bytes) from the plain text file and sort them:
  - grep "Rx Rate (Percent)" <xena2889-report.txt> | sed 'n;d' | tr -s ' ' | cut -d " " -f 4
    - in case of if values for the frame size of 1518 is shown in separate lines:
      - sed 'n;d' – skip every second line, which has value for the frame size of 1518 bytes
      - sed '1~2d' – skip every second line starting from line 1 (used to read the values for the frame size of 1518)
- replace "0%" with "0 %" in .txt file:
  - sed -i 's/\b0%/0 %/g' <xena2889-report.txt>
- extract the average, minimum and maximum latency values from the broadcast forwarding test results (eg., frame size = 64 bytes):
  - for str in Avg Min Max; do echo $str; grep "$str Latency" <xena2889-report.txt> | head -17 | tr -s ' ' | cut -d " " -f 5 | sort -g; done

1.1. Full Mesh Test
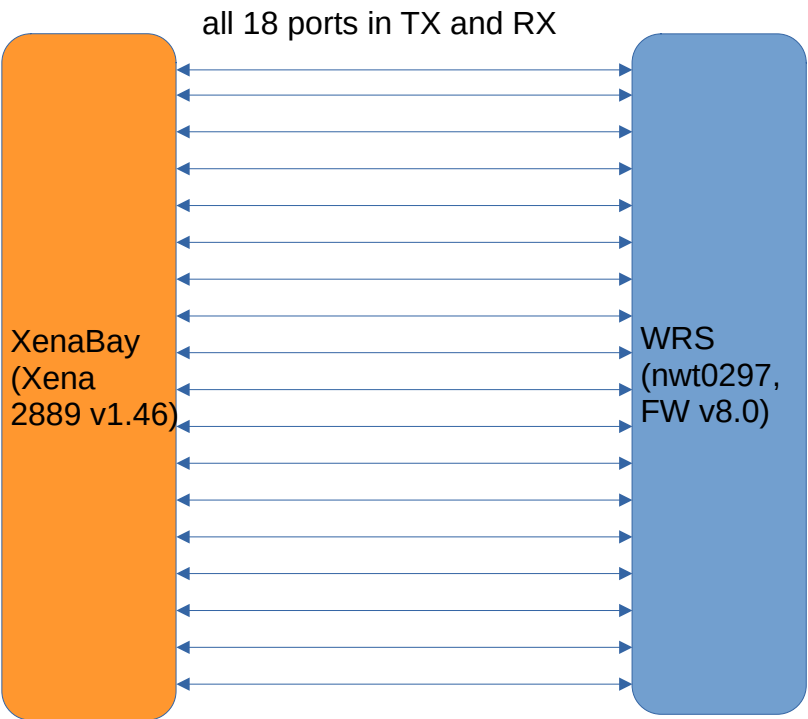
all 18 ports in TX and RX

XenaBay
(Xena
2889 v1.46)

WRS
(nwt0297,
FW v8.0)

Forwarding test

Frame Size, bytes >	64		128		256		512		1024		1518	
Tx, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %
10	7,6	24	7,77	22,26	7,82	21,79	8,02	19,75	8,03	19,74	7,62	23,82
20	0,03	99,87	12,11	39,47	12,02	39,92	12,15	39,26	12,17	39,15	12,08	39,6
30	0,02	99,95	16,37	45,42	16,66	44,46	16,69	44,37	16,57	44,78	16,43	45,23
40	0,01	99,97	0,03	99,92	20,57	48,57	20,59	48,53	20,58	48,54	20,59	48,51
50	0,01	99,98	0,03	99,95	25,35	49,29	25,35	49,29	25,57	48,87	25,43	49,15
60	0,01	99,99	0,02	99,96	1,77	97,05	29,23	51,28	29,19	51,36	28,94	51,77
70	0,01	99,99	0,02	99,97	0,06	99,92	34,25	51,07	34,5	50,71	34,19	51,15
80	0,01	99,99	0,02	99,98	0,05	99,94	37,7	52,88	37,92	52,61	38	52,5
90	0,01	99,99	0,01	99,98	0,03	99,97	11,89	86,79	11,97	86,7	23,64	73,74
100	0	100	0,01	99,99	0,03	99,97	11,84	88,16	9,44	90,56	14,76	85,24

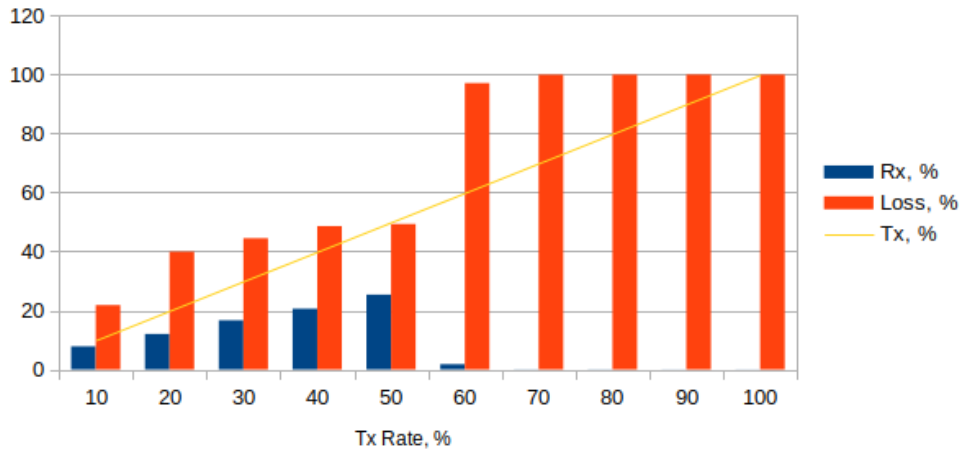Table 1.1.a. Forwarding rate test results

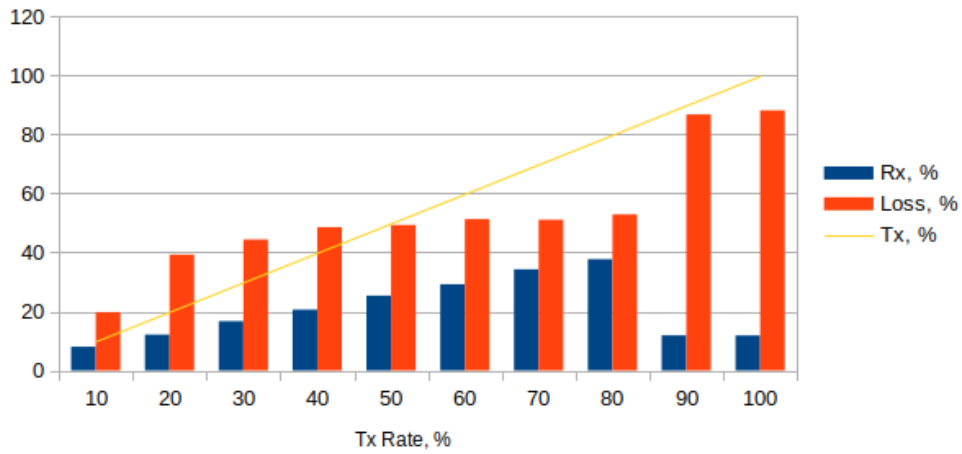Forwarding rate, full mesh , frame size = 64 bytes
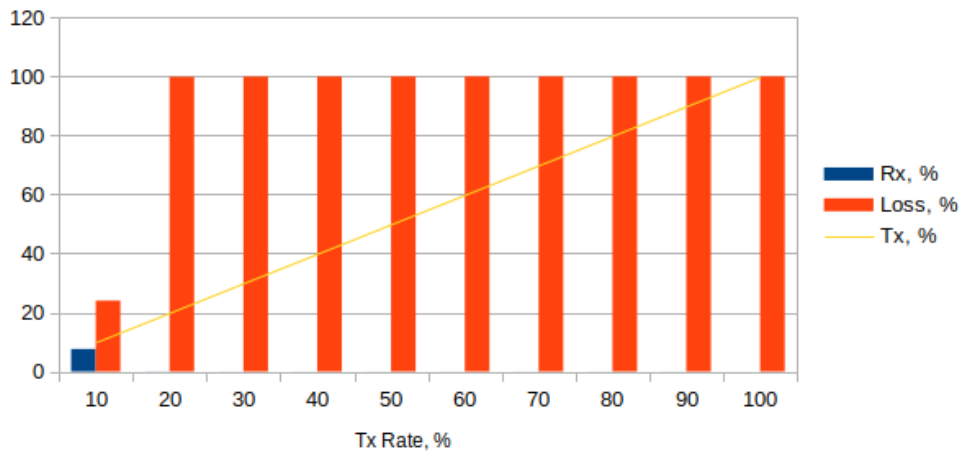
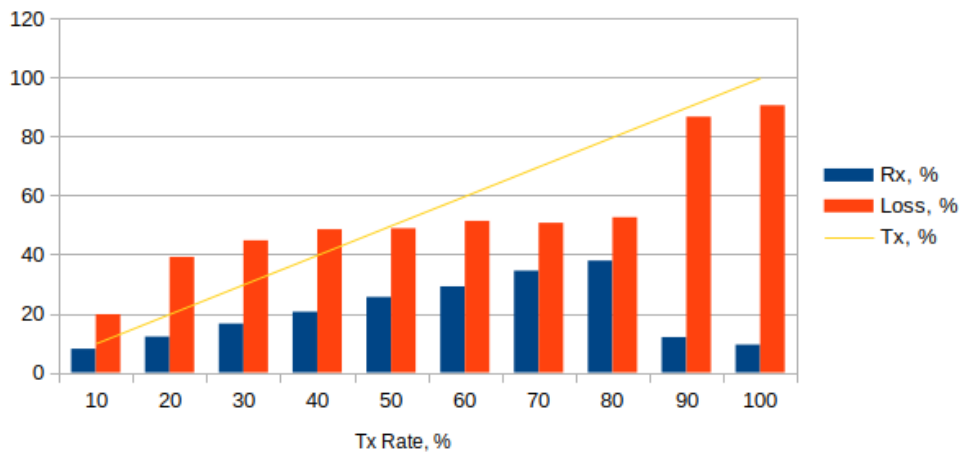Forwarding rate, full mesh, frame size = 128 bytes
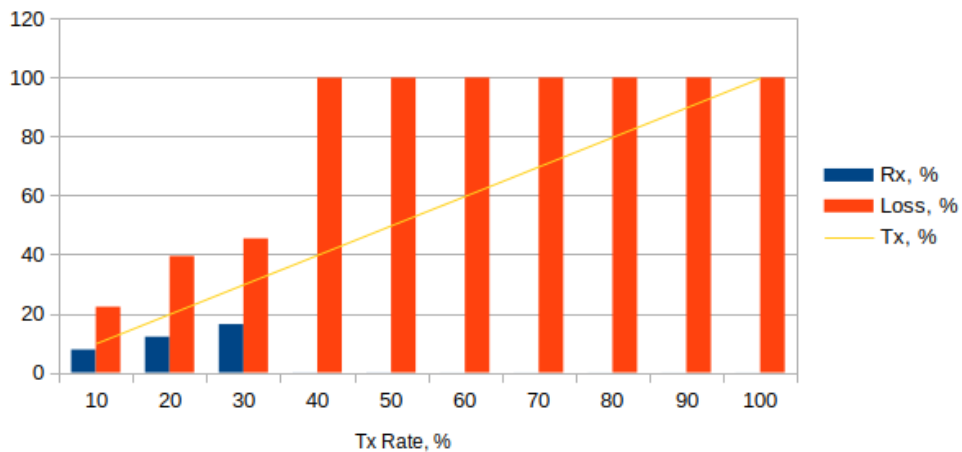
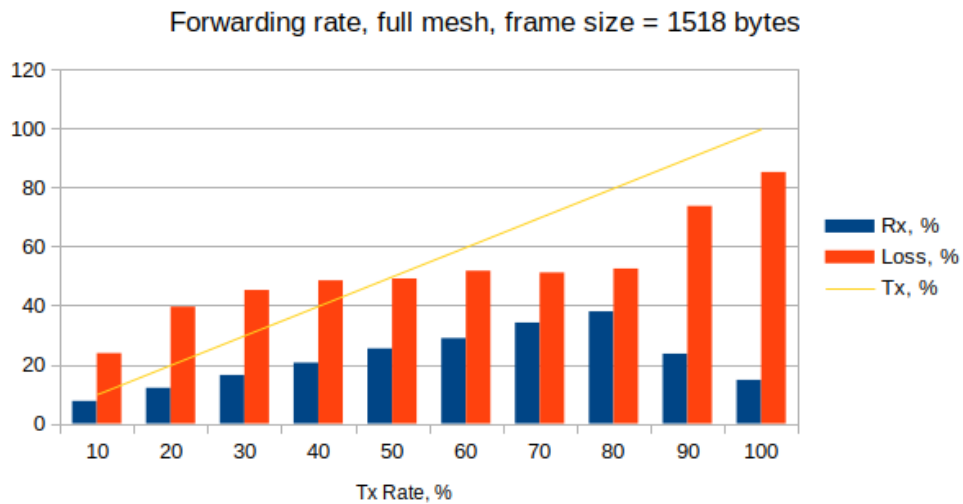## Forwarding rate, full mesh, frame size = 256 bytes

Forwarding rate, full mesch, frame size = 512 bytes

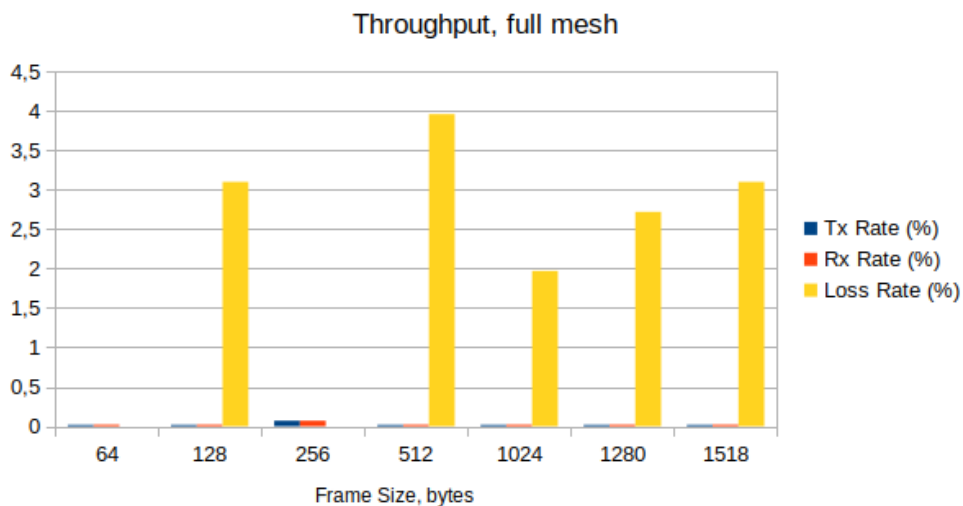## Forwarding rate, full mesh, frame size = 1024 bytes

Forwarding rate, full mesh, frame size = 1518 bytes

Throughput test

Frame Size, bytes	Tx Rate, %	Tx Rate, b/s	Tx Rate, f/s	Rx Rate, %	Loss Rate, % (frames)	Result
64	0,018	3,2M	4743	0,02	0 (0)	Pass
128	0,018	3,2M	2693	0,02	3,1 (2489)	Fail
256	0,072	12,9M	5855	0,07	0 (0)	Pass
512	0,018	3,2M	745	0,02	4 (884)	Fail
1024	0,018	3,2M	377	0,02	2 (223)	Fail
1280	0,018	3,2M	306	0,02	2,7 (250)	Fail
1518	0,018	3,1M	255	0,02	3,1 (233)	Fail

Table 1.1.b. Throughput test results

Throughput, full mesh

1.2. Partial 1:N Mesh Test
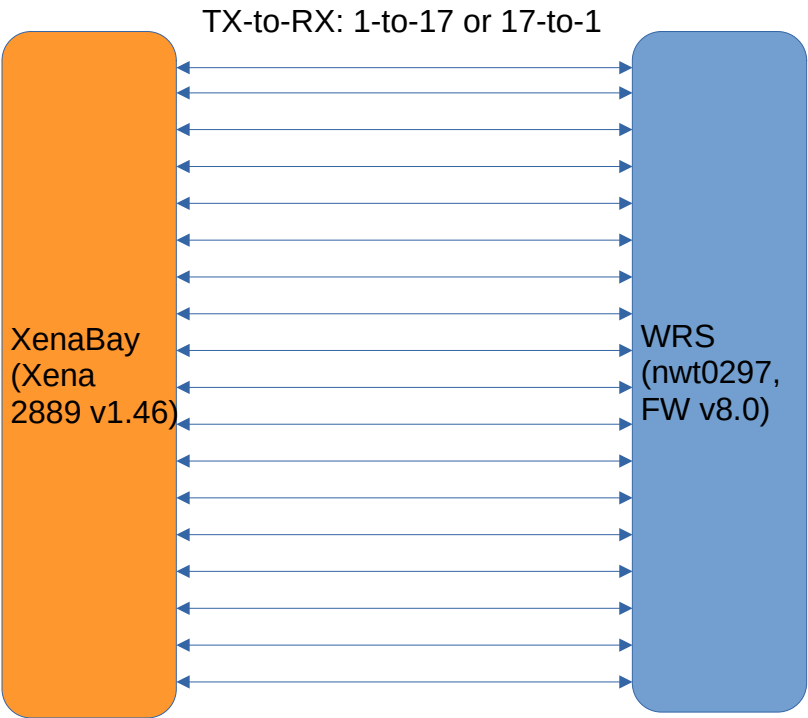
TX-to-RX: 1-to-17 or 17-to-1

XenaBay (Xena 2889 v1.46)

WRS (nwt0297, FW v8.0)

Forwarding test

| Frame Size, bytes >	64		128		256		512		1024		1518	
Tx, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %
10	5,72	42,79	5,83	41,69	5,91	40,92	5,95	40,49	6,04	39,59	5,72	42,82
20	0,03	99,87	6,08	69,61	6,15	69,25	6,21	68,94	6,21	68,94	5,76	71,21
30	0,01	99,96	6,19	79,38	6,44	78,53	5,95	80,18	6,48	78,4	4,29	85,7
40	0,01	99,98	0,02	99,96	6,21	84,47	6,71	83,22	6,32	84,2	5,92	85,2
50	0,01	99,98	0,01	99,97	6,44	87,12	6,84	86,32	6,81	86,38	6,2	87,6
60	0,01	99,99	0,01	99,98	1,97	96,71	6,81	88,64	6,61	88,98	5,99	90,02
70	0,01	99,99	0	99,99	0,15	99,78	7,17	89,75	7,07	89,9	6,02	91,4
80	0,01	99,99	0,01	99,99	0,02	99,98	6,51	91,87	7,1	91,12	6,11	92,36
90	0	100	0,01	99,99	0	100	6,68	92,58	6,78	92,46	6,09	93,24
100	0	100	0,01	99,99	0,02	99,98	0	100	6,77	93,23	0	100

Table 1.2.a. Forwarding rate test results
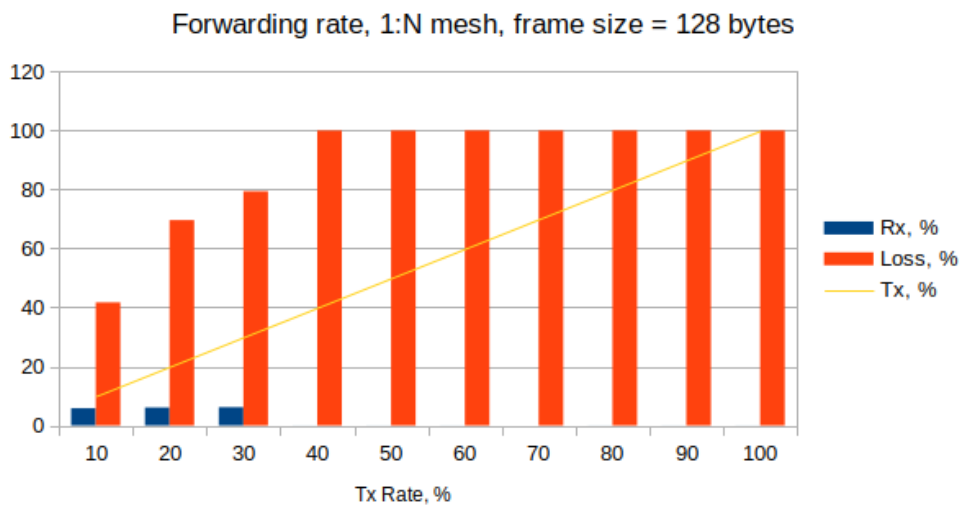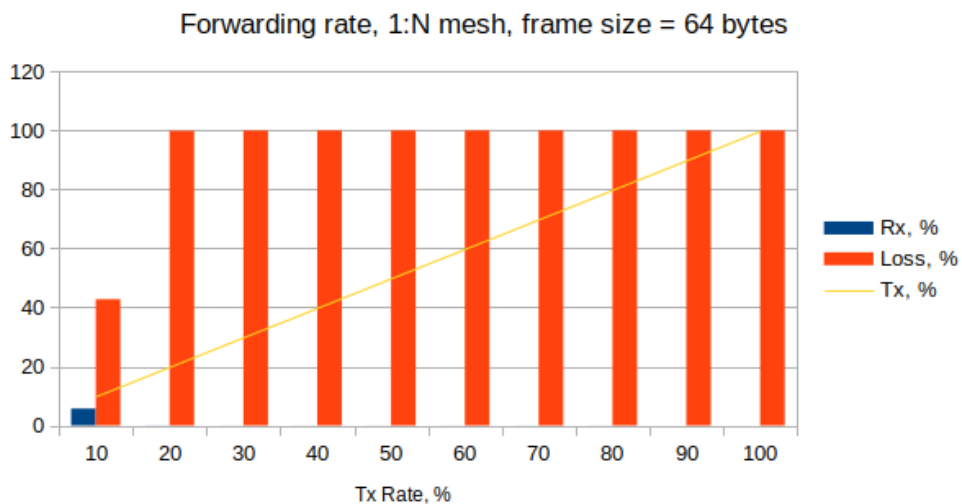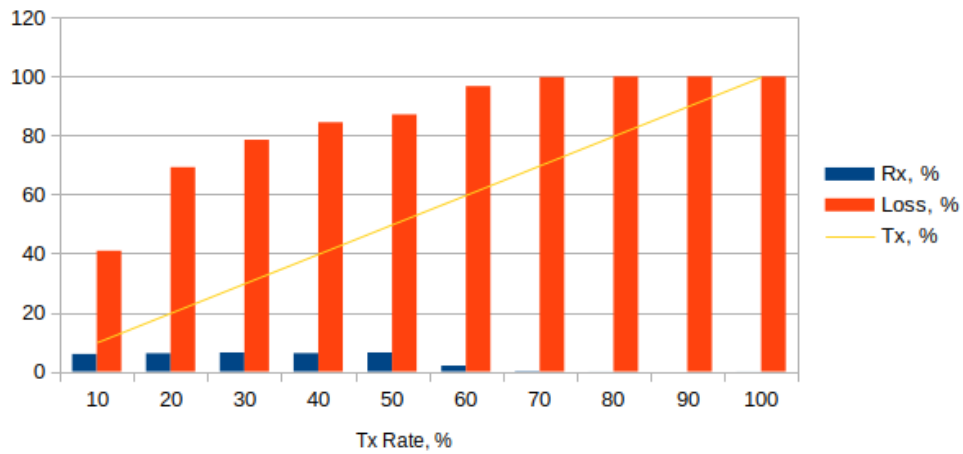
Forwarding rate, 1:N mesh, frame size = 64 bytes

Forwarding rate, 1:N mesh, frame size = 128 bytes
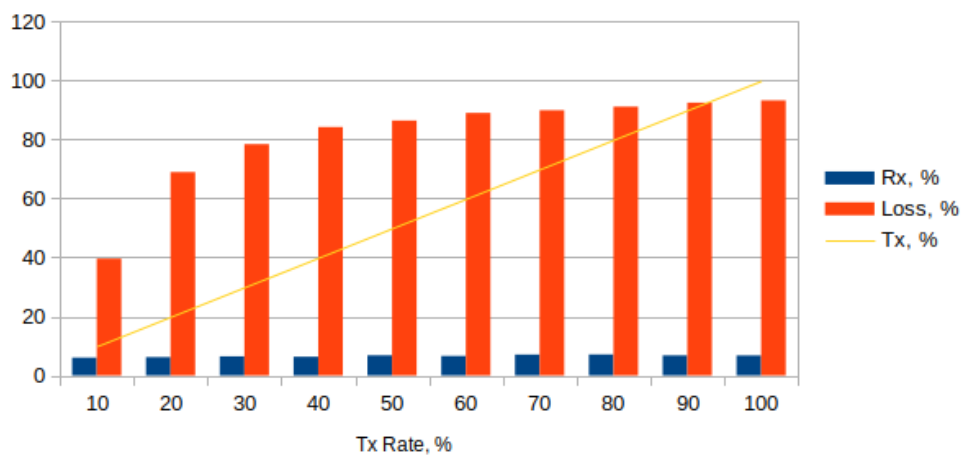
Forwarding rate, 1:N mesh, frame size = 256 bytes

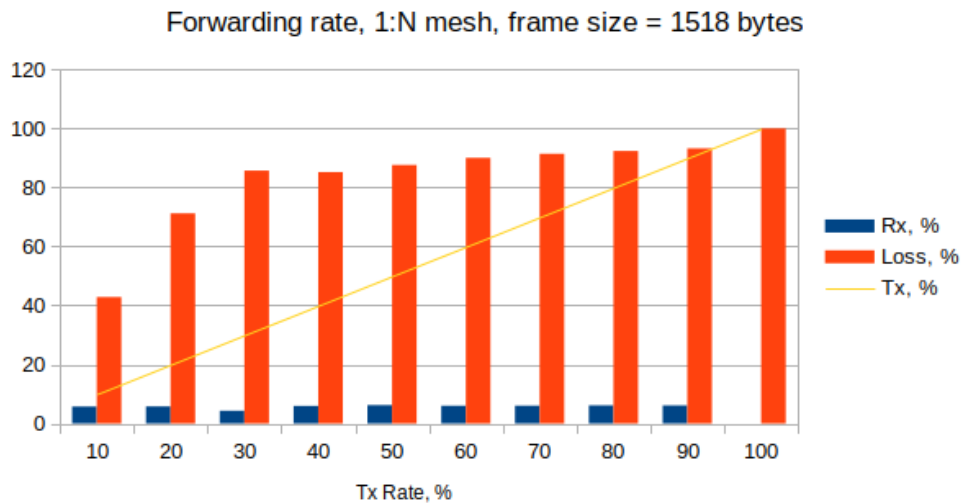## Forwarding rate, 1:N mesh, frame size = 512 bytes

Forwarding rate, 1:N mesh, frame size = 1024 bytes
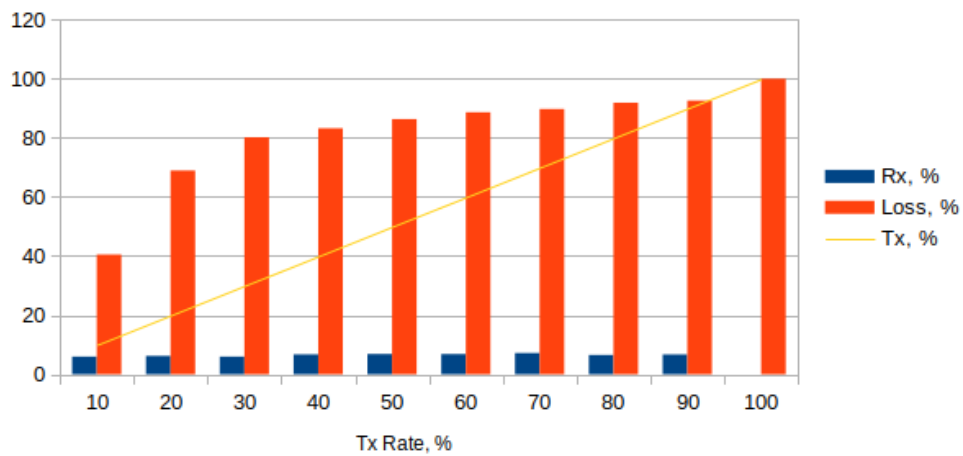
Forwarding rate, 1:N mesh, frame size = 1518 bytes

Throughput test

Frame Size, bytes	Tx Rate, %	Tx Rate, b/s	Tx Rate, f/s	Rx Rate, %	Loss Rate, % (frames)	Result
64	0,018	3,2M	4750	0,02	2,6 (3712)	Fail
128	0,018	3,2M	2696	0,02	1,7 (1383)	Fail
256	0,018	3,2M	1445	0,02	0,7 (280)	Fail
512	0,018	3,2M	750	0,02	1,3 (281)	Fail
1024	0,018	3,2M	382	0,02	6,7 (764)	Fail
1280	0,018	3,2M	307	0,02	1,6 (148)	Fail
1518	0,018	3,2M	259	0,02	0,9 (73)	Fail

Table 1.2.b. Throughput test results
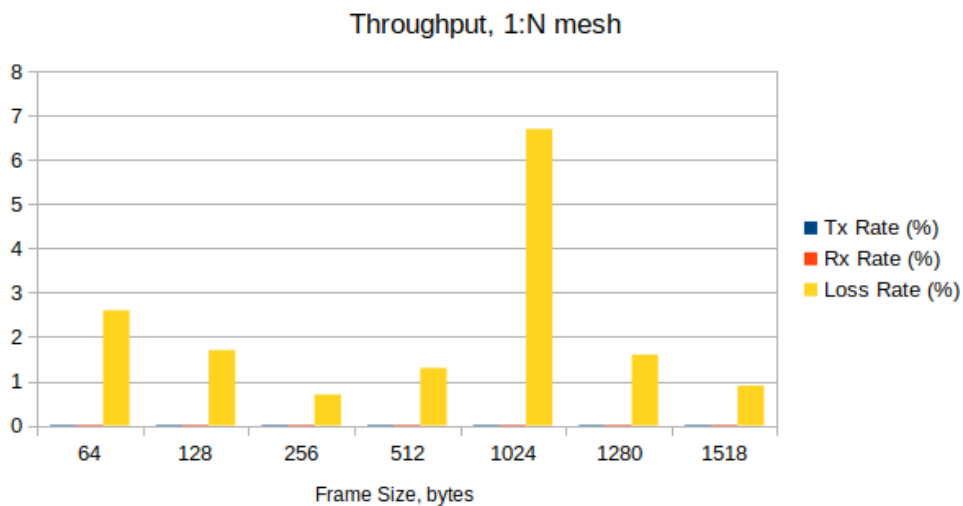
Throughput, 1:N mesh

1.3. Partial N:N Mesh Test
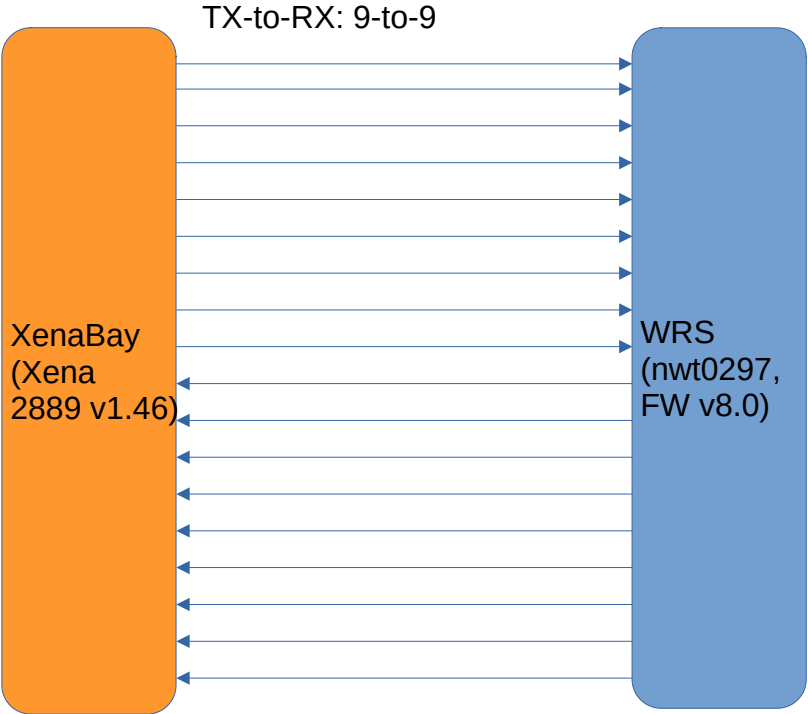
TX-to-RX: 9-to-9

XenaBay
(Xena
2889 v1.46)

WRS
(nwt0297,
FW v8.0)

Forwarding test

Frame Size, bytes >	64		128		256		512		1024		1518	
Tx, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %	Rx, %	Loss, %
10	9,38	6,21	9,92	0,76	9,69	3,06	9,43	5,68	9,78	2,23	9,38	6,24
20	10,62	46,91	10,83	45,86	10,95	45,23	11,03	44,83	11,01	44,93	11,09	44,57
30	10,61	64,65	10,81	63,97	10,96	63,45	11,04	63,21	11,07	63,1	10,94	63,52
40	0,02	99,95	10,83	72,92	10,96	72,6	10,8	72,99	11,04	72,4	11,09	72,27
50	0,01	99,97	10,83	78,34	10,92	78,15	10,9	78,19	11,07	77,85	10,99	78,02
60	0,01	99,98	10,74	82,1	10,46	82,56	11,04	81,61	11,05	81,58	11	81,66
70	0,01	99,98	0,85	98,79	10,96	84,34	11,04	84,23	11,08	84,17	11,01	84,27
80	0,01	99,99	0,02	99,98	10,97	86,29	10,91	86,37	11,07	86,16	10,89	86,38
90	0,01	99,99	0,02	99,98	10,87	87,93	10,94	87,84	11,08	87,69	11,09	87,67
100	0,01	99,99	0,02	99,98	10,96	89,04	11,04	88,96	11,05	88,95	11,05	88,95

Table 1.3.a. Forwarding rate test results
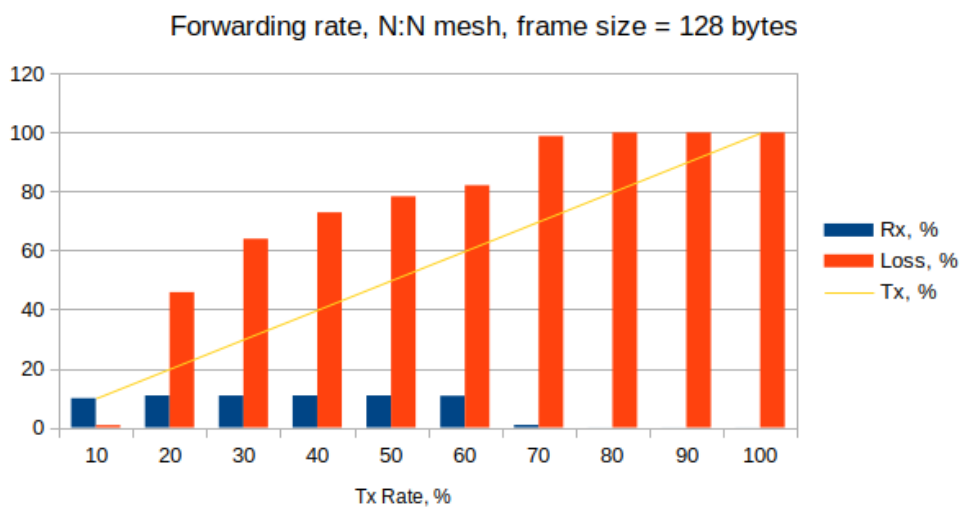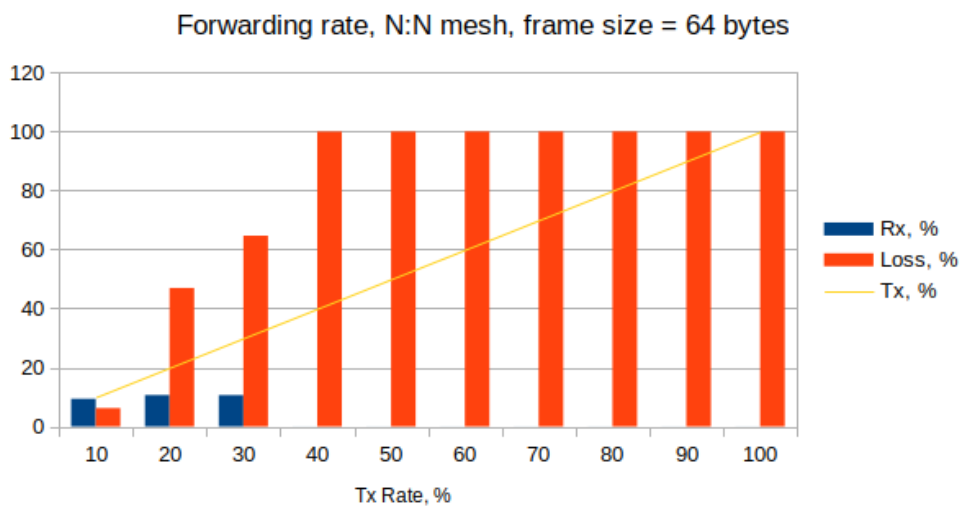
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Forwarding rate, N:N mesh, frame size = 256 bytes
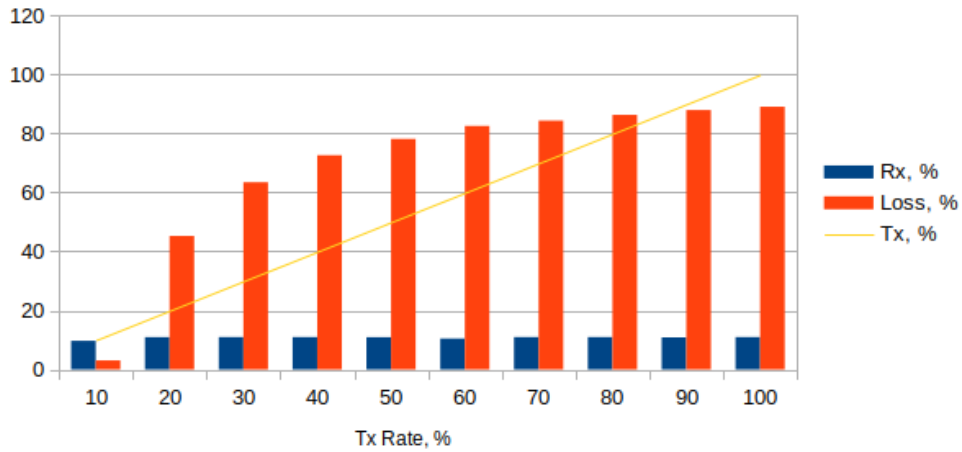
Forwarding rate, N:N mesh, frame size = 512 bytes

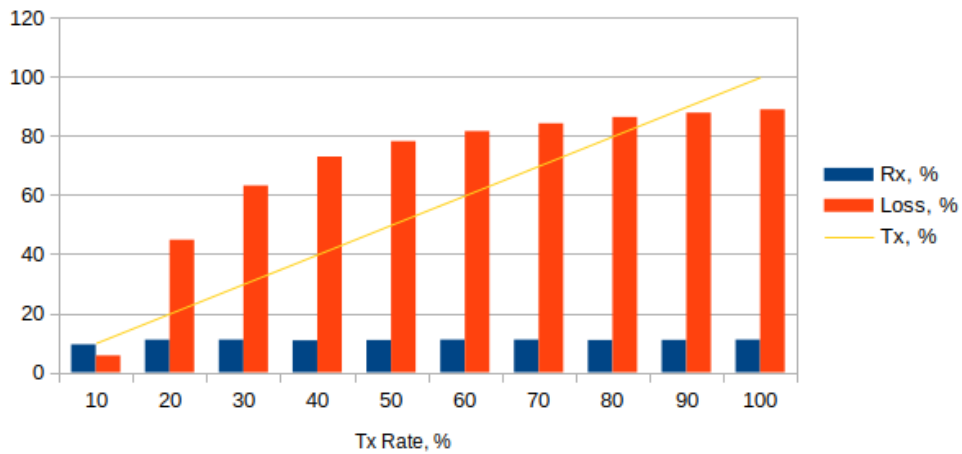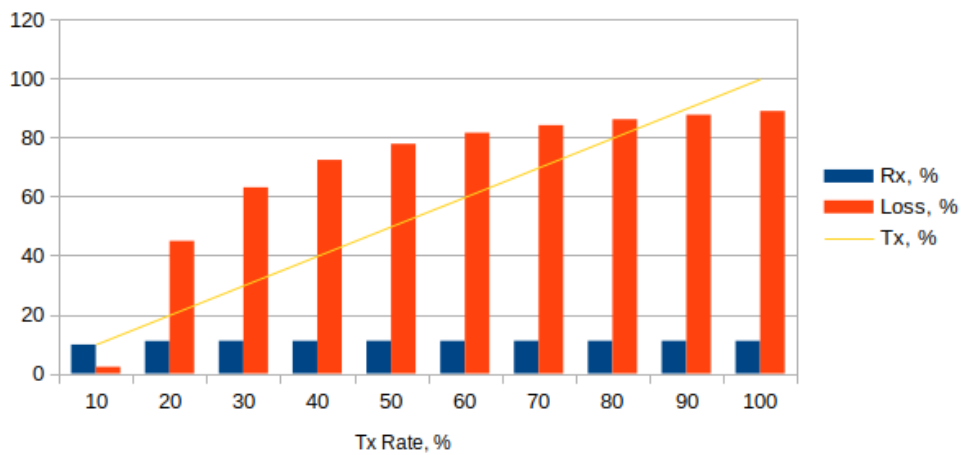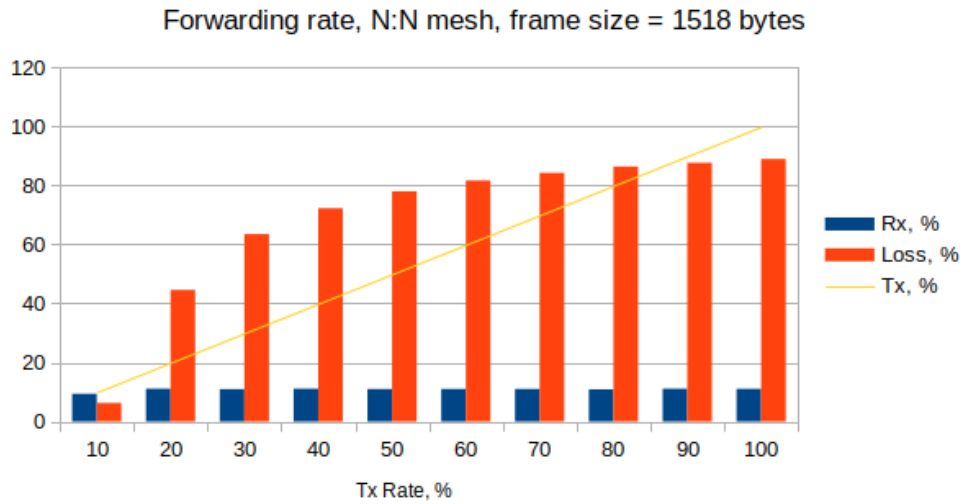## Forwarding rate, N:N mesh, frame size = 1024 bytes

Forwarding rate, N:N mesh, frame size = 1518 bytes

Throughput test

Frame Size, bytes	Tx Rate, %	Tx Rate, b/s	Tx Rate, f/s	Rx Rate, %	Loss Rate, % (frames)	Result
64	0,018	1,6M	2373	0,02	1,6 (1146)	Fail
128	0,018	1,6M	1347	0,02	0,8 (330)	Fail
256	0,018	1,6M	721	0,02	1,4 (296)	Fail
512	0,018	1,6M	373	0,02	1,7 (187)	Fail
1024	0,018	1,6M	189	0,02	5 (284)	Fail
1280	0,018	1,6M	151	0,02	0,04 (2)	Fail
1518	0,018	1,6M	130	0,02	2,2 (84)	Fail

Table 1.3.b. Throughput test results

Throughput, N:N mesh
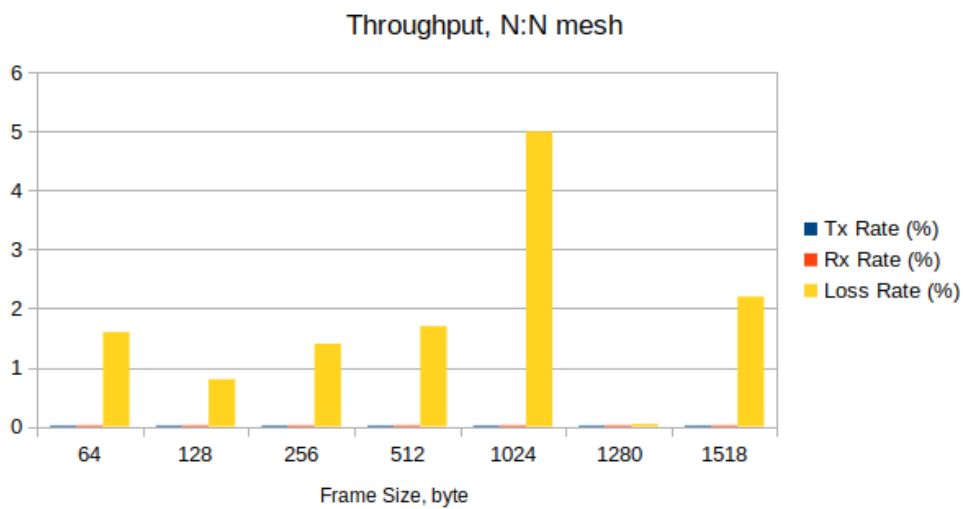
1.4. Congestion Control Test
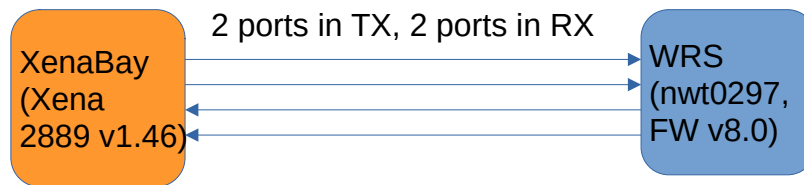
Frame Size	Tx Rate, %	Tx Frames	UC-Port: Tx	UC-Port: Rx	UC-Port: Loss, %	C-Port: Tx	C-Port: Rx	C-Port: Loss, %	Result
64	100	89285716	22321429	22321429	0	66964287	42621942	36,35	Pass
128	100	50675677	12668920	12668920	0	38006757	24672541	35,08	Pass
256	100	27173914	6793479	6793479	0	20380435	13393816	34,28	Pass
512	100	14097746	3524437	3524437	0	10573309	6996695	33,83	Pass
1024	100	7183910	1795978	1795978	0	5387932	3578526	33,58	Pass
1280	100	5769232	1442308	1442308	0	4326924	2875992	33,53	Pass
1518	100	4876464	1219116	453249	765867	3657348	2432092	33,50	Fail

Table 1.4. Congestion control test results (C-Port: Congested Port, UC-Port: Uncongested Port)

1.5. Forward Pressure Test
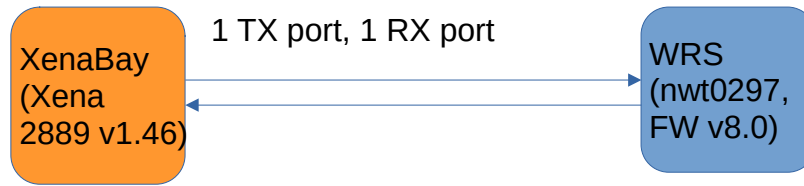
Frame Size, bytes	Tx Frames	Tx max. util., %	Rx Frames	Rx max. util., %	Loss, %	Result
64	45180722	101,205	42613630	95,45	5,68	Pass
128	25510204	100,68	24671078	97,368	3,29	Pass
256	13636363	100,364	13392895	98,571	1,79	Pass
512	7062146	100,188	6996318	99,254	0,93	Pass
1024	3595397	100,096	3578299	99,618	0,48	Pass
1280	2886836	100,077	2875824	99,693	0,38	Pass
1518	2439817	100,065	2431962	99,74	0,32	Pass

Table 1.5. Forward pressure test results

1.6. Maximum Forwarding Rate Test
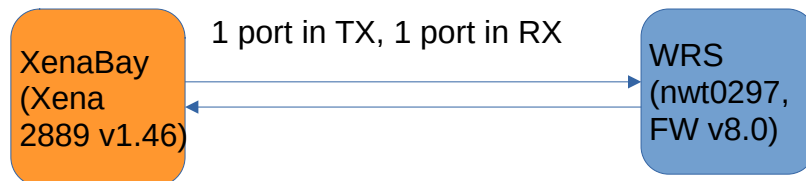
Frame Size, bytes	Tx Rate, %	Tx Rate, f/s	Tx Frames	Rx Frames	Loss, % (calculated)	Result
64	90	1339,5K	40186488	40186488	0	Pass
128	100	844,6K	25337837	24602240	2,9	Pass
256	100	452,9K	13586956	13392925	1,4	Pass
512	100	235K	7048872	6996333	0,7	Pass
1024	100	119,7K	3591954	3578309	0,4	Pass
1280	90	86,5K	2596153	2596153	0	Pass
1518	100	81,3K	2438231	2431967	0,26	Pass

Table 1.6. Maximum forwarding rate test results

1.7. Address Caching Capacity and Learning Rate Tests
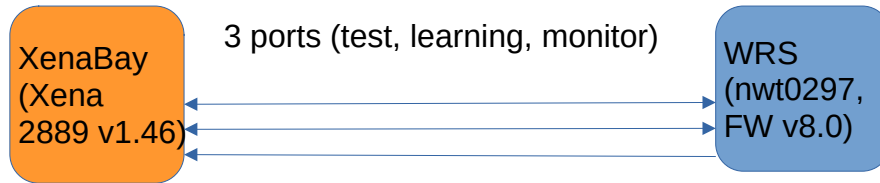
Address Caching Capacity (Learning Rate=20 Frames/s, DUT aging=310 seconds)

Frame Size, bytes	Address Count	Test Port Tx Frames	Learn Port Rx Frames	Monitor Port Rx Frames	Result
64	1074	22	22	22	Fail
128	100	22	22	22	Fail
256	100	22	22	22	Fail
512	100	22	22	22	Fail
1024	100	22	22	22	Fail
1280	100	22	22	22	Fail
1518	100	22	22	22	Fail

Table 1.7.a. MAC address caching capacity test results

Address Learning Rate (percent), frame/s (DUT aging=310 seconds)

Frame size, byte / Address count	64	128	256	512	1024	1280	1518
100	20	20	20	20	20	20	20
300	20	20	20	20	20	20	20
500	20	20	20	20	20	20	20
700	20	20	20	20	20	20	20
900	20	20	20	20	20	20	20
1100	20	20	20	20	20	20	20
1300	20	20	20	20	20	20	20
2048	20	20	20	20	20	20	20

Table 1.7.b. MAC address learning rate test results

Issue: With the aging time of 310 seconds (300 seconds for WR switches by default) is chosen for the reset condition, the **address caching capacity test is failed**. Here, switch starts to forward test packets (100, 1074) properly, no flooding. At iteration with the critical number of packets (1561) it floods, and then it remains to flood in all further iterations with decreasing number of the test packets (1317, 1195, …, 1075, 1074). The test is failed because the switch floods even with the same number of packets (1074), with which no flooding was happened in previous iteration.

1.8. Errored Frames Filtering Test

XenaBay (Xena 2889 v1.46) — 1 port in TX, 1 port in RX → WRS (nwt0297, FW v8.0)
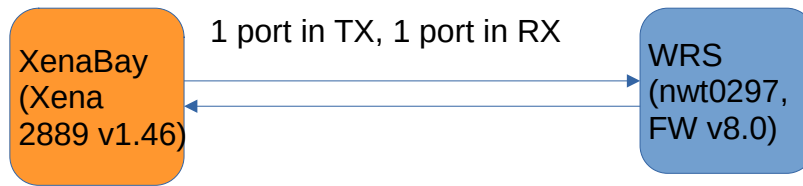
| Tx Rate, %	Tx Valid	Rx Valid	Tx Over size	Rx Over size	Tx Under size	Rx Under size	Tx FCS Error	Rx FCS Error	Result
10	154130	154130	81221	81221	1506024	1505950	59	0	Fail
20	308261	308261	162443	162443	3012048	3003506	58	0	Fail
30	462392	462392	243664	243664	4518072	4445299	58	0	Fail
40	616522	616522	324886	324886	6024096	5747243	58	0	Fail
50	770653	770653	406107	406107	7530120	7100619	58	0	Fail
60	924784	924784	487329	487329	9036144	8339676	58	0	Fail
70	1078914	1078914	568551	568551	10542168	9458800	58	0	Fail
80	1233045	1233045	649772	649772	12048192	10729227	58	0	Fail
90	1387176	1387176	730994	730994	13554216	11944767	58	0	Fail
100	1541307	1478061	812215	629321	15060240	11621558	58	0	Fail

Table 1.8. Errored frames filtering test results

1.9. Broadcast Forwarding Test
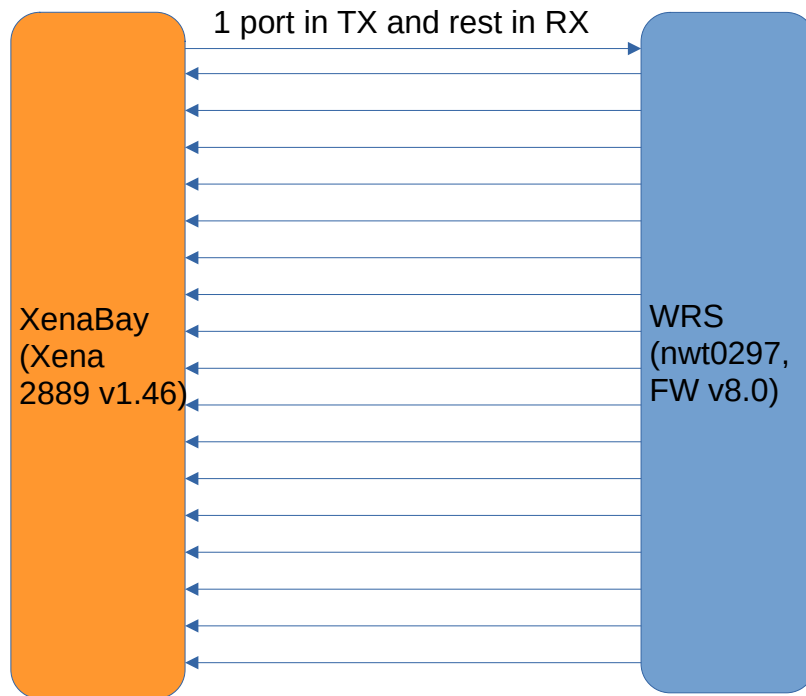
Frame Size, bytes	Tx Rate, %	Loss Rate, %	Loss Frames	Result
64	66,3	0	0	Pass
128	77,9	0	0	Pass
256	83,1	0	0	Pass
512	91,6	0	0	Pass
1024	94,4	0	0	Pass
1280	94,4	0	0	Pass
1518	94,4	0	0	Pass

Table 1.9.a. Broadcast forwarding test results
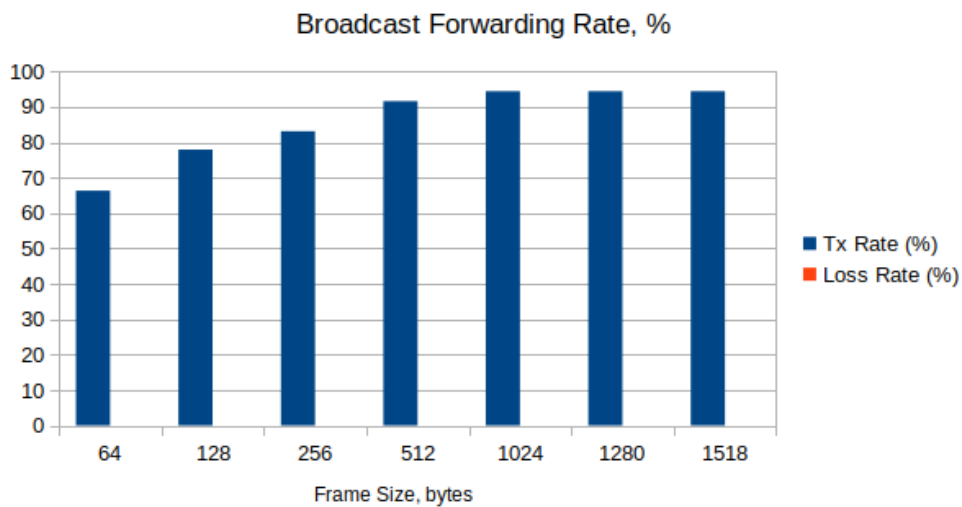
Frame Size, bytes	Tx Rate (Fps)
64	986517
128	657530
256	376472
512	215137
1024	112997
1280	90745
1518	76703

Table 1.9.b. Broadcast throughput test results
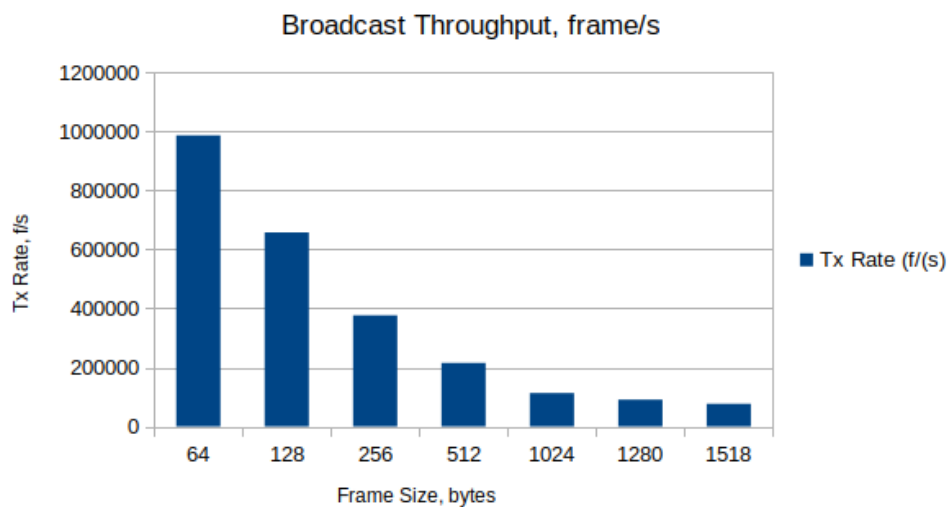
Frame Size, bytes	Latency, usec			Jitter, usec		
	Average	Min	Max	Average	Min	Max
64	2,5-4,9	1,6-2,3	6,2-10,6	0,003	0	2,1-2,8
128	2,9-6,7	2,1-2,8	6-12,7	0,002	0	2-2,3
256	2,3-3	2-2,7	4,7-6	0,008-0,01	0	2,2-2,5
512	3-121,6	2-2,8	6,4-240,1	0,002	0	2-2,2
1024	2,3-3	2,1-2,8	4,6-6,4	0,003-0,004	0	2,2-2,5
1280	2,3-3	2,1-2,8	4,4-5,3	0,004-0,006	0	2,2-2,6
1518	2,3-3	2-2,7	4,3-5,3	0,002-0,003	0	2,1-2,4

Table 1.9.c. Latency and jitter measurements in broadcast forwarding

Broadcast Forwarding Average Latency, usec

Broadcast Forwarding Average Jitter, usec