

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 (140.181.139.228)
- software: Valkyrie2889 **v1.40**, MS Windows 8.1 Enterprise Evaluation (VirtualBox guest)
- configuration: https://github.com/GSI-CS-CO/network_testing
 - wr_RFC_2889/xena_cfg/RFC_2889_1_switch_Xena.v2889
 - wr_RFC_2889/xena_cfg/RFC_2889_4_switches_Xena.v2889

As a device under test the WR switch from Creotech (model WRS-3/18) with the HW version v3.4 and SW version v6.1 is chosen.

In general, 2 test setups are built for benchmarking:

- single WR switch and
- 4 layers of the WR switch

Some sub-tests have been failed because of not optimal configuration and repeated again with suitable parameters. All test results are recorded into following files:

- ~~xena2889-report-20230928-222005.pdf~~ (initial test, 1 switch, todo: repeat the throughput, address caching and learning tests with suitable setups)
- xena2889-report-20231023-194401.pdf (1 switch, address caching capacity test, aging time = 350 seconds)
- xena2889-report-20231023-195822.pdf (1 switch, address caching capacity test, switch test ports)
- xena2889-report-20231107-222240.pdf (1 switch, complete test)
- ~~xena2889-report-20231108-191929.pdf~~ (initial test, 4 switches, todo: repeat 1:N & N:N tests with different topologies)
- xena2889-report-20231113-173928.pdf (4 switches, N:N mesh)
- xena2889-report-20231114-122401.pdf (4 switches, 1:N mesh)
- xena2889-report-20231114-201104.pdf (4 switches, tests except 1:N and N:N meshes)

Similar to the previous test, which was done in 2016, 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 **green**.

Moreover, test results are compared with the results of previous test and comparison results are coded as follows: better than v4.2 (+), worse than v4.2 (-) and not much different than v4.2 (=).

For test report of 2016 refer to:

https://www-acc.gsi.de/wiki/pub/Timing/TimingSystemDocumentsReportsAndMeasurements/WR_Switch_RFC_2889.pdf

1 WR switch

Test results in 'xena2889-report-20231107-222240.pdf' are evaluated.

- **Traffic test**: for all predefined frame lengths (64-1518 bytes) and bandwidths (10-100%, 100M-1Gb/s) there are frame losses. RX rates never achieve corresponding TX rates. Throughput cannot be determined for all frame lengths by a single test.
 - **full mesh (-)**: maximum total throughput are around 4,5Mb/s and 4,9Mb/s and can be determined only for the frame sizes of 128 and 1280 bytes. For a single port they correspond to 253 and 273Kb/s data rate.
 - **partial 1:N mesh (=)**: maximum total throughput reached to 90,9Mb/s for the frame size of 256 bytes and 46,36Mb/s for the frame size of 512 bytes.
 - **partial N:N mesh (-)**: maximum total throughput are 13,43Mb/s and 1,57Mb/s for the frame sizes 256 and 1280 bytes.
- **Congestion control (=)**: no congestion control. Neither 'head of line blocking' (for uncongested port) nor back pressure (for congested port) is detected. Test for the frame size of 1518 bytes is passed when the test is repeated.
- **Forward pressure (=)**: no 'forward pressure' is detected and switch can guarantee the interframe gap (IFG) of 96-bits.
- **Maximum forwarding rate (=)**: maximum TX rate is achieved with frame loss. For shorter frame sizes (64 and 128 bytes) the loss rates are higher (4,54% and 2,63%). The frame loss decreases when frame size gets larger (1,43% to 0,25%).
- **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 1500 MAC addresses. The minimum address count is 769 for frame size of 1518 bytes. 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 software versions including v4.2, v5.0.1, v6.0 and v6.1. **Hence, address aging must be checked.**
- **Errorred frames filtering (=)**: oversized and undersized frames cannot be filtered, but invalid FCS frames. Ignore lost frames at the highest data rate (refer to maximum forwarding rate test).
- **Broadcast forwarding (=)**: better broadcasting performance (over 90%, 900 Mb/s) for frames equal or larger than 512 bytes. The lowest forwarding rate is 66% (660 Mb/s) for 64 bytes frame length.

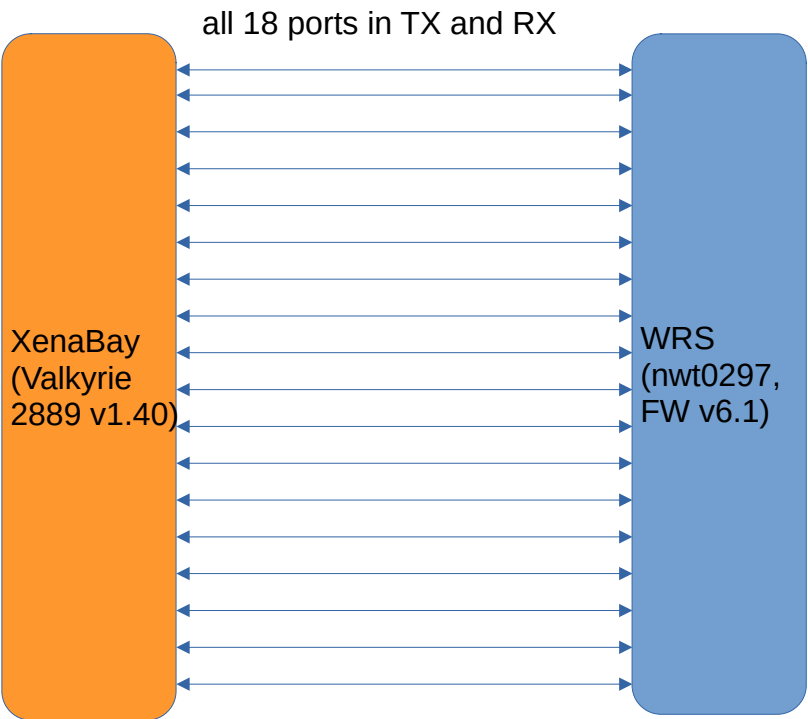
4 layers of the WR switch

Test results in following files are evaluated:

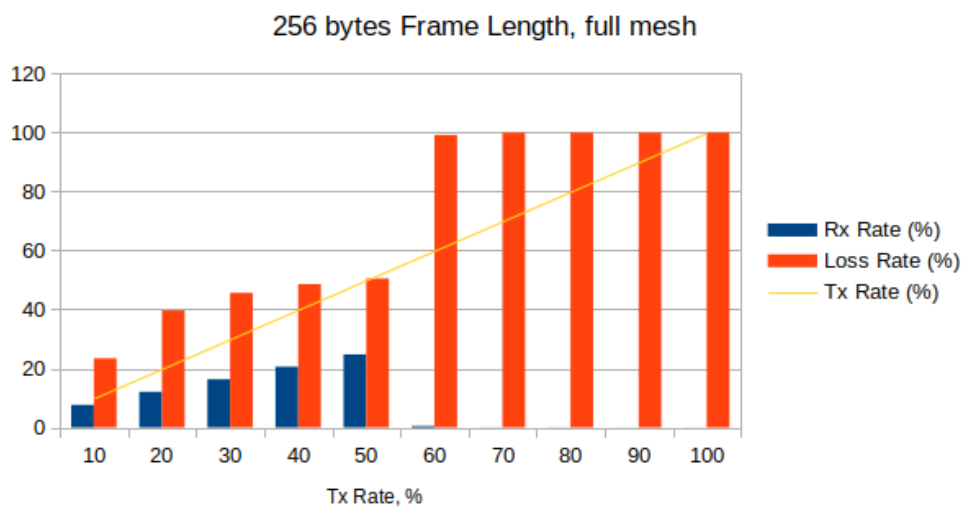
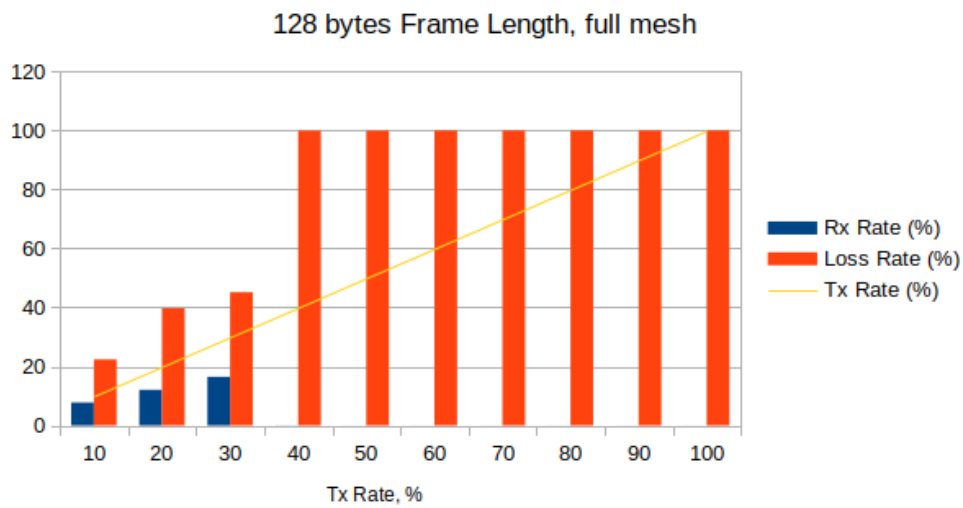
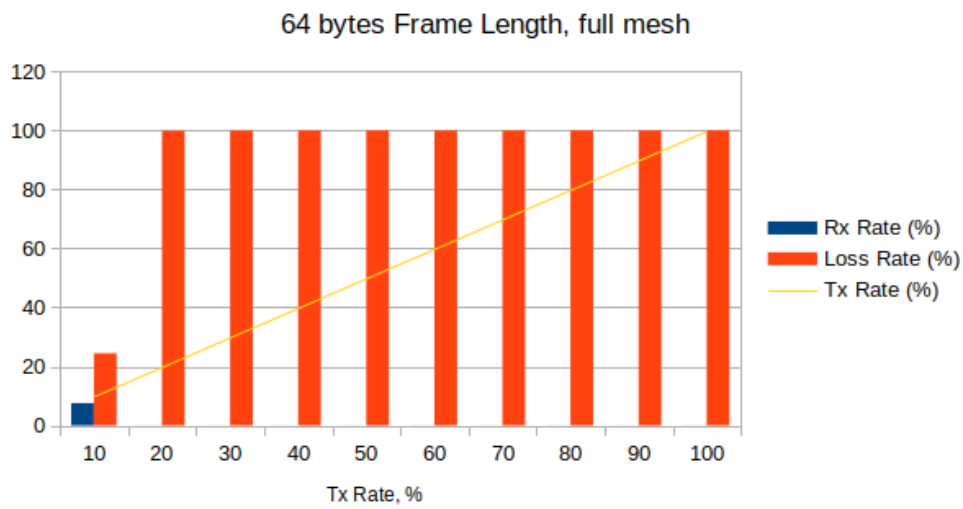
- xena2889-report-20231113-173928.pdf (4 switches, N:N mesh)
- xena2889-report-20231114-122401.pdf (4 switches, 1:N mesh)
- xena2889-report-20231114-201104.pdf (4 switches, tests except 1:N and N:N meshes)

Next sections present the performed test results in graphs.

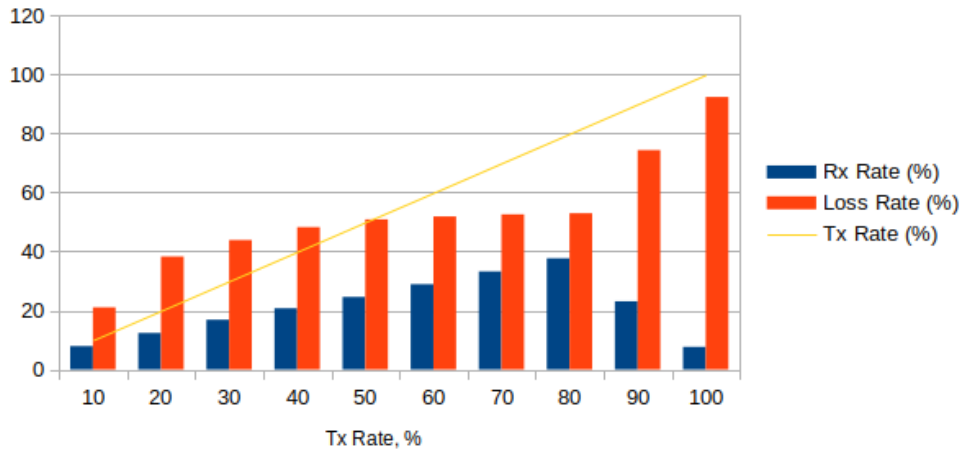
1.1. Full Mesh Results



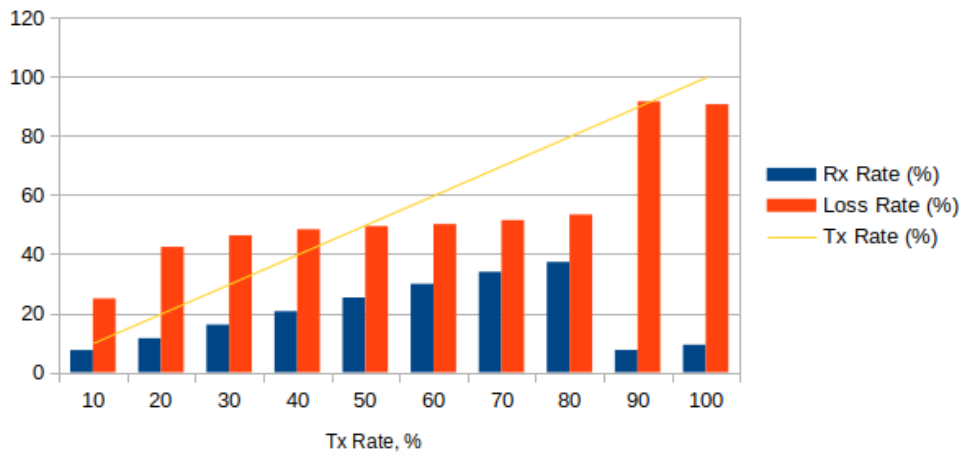
Forwarding test



512 bytes Frame Length, full mesh

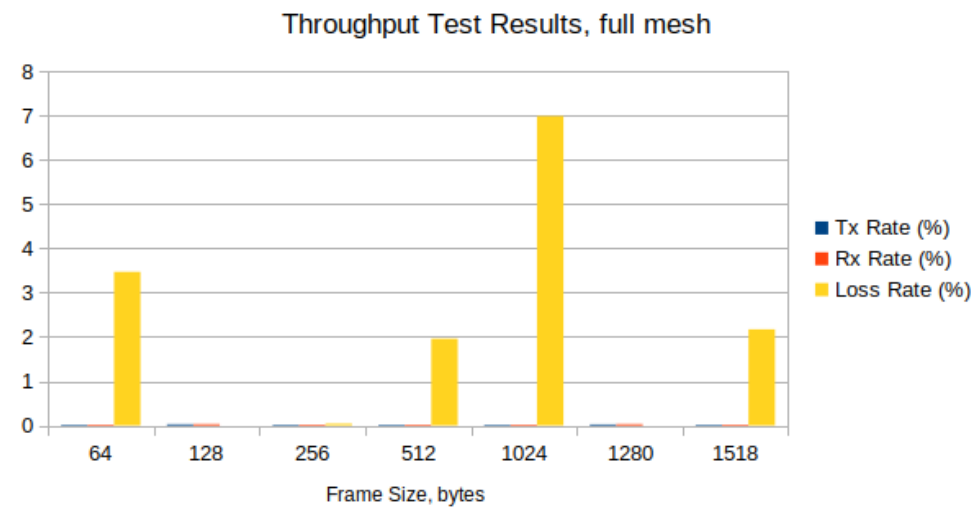


1518 bytes Frame Length, full mesh



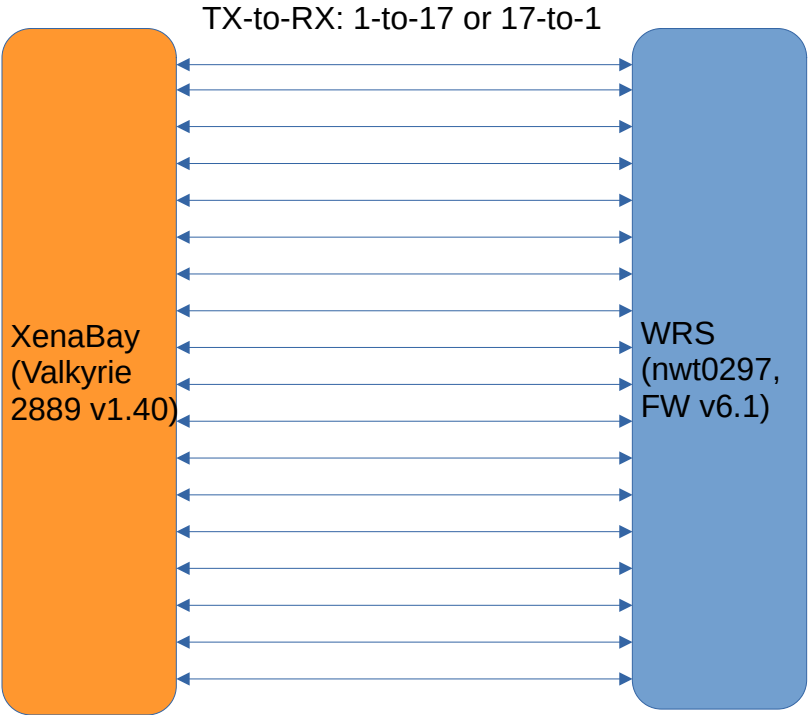
Frame Length	64 bytes		128 bytes		256 bytes		512 bytes		1024 bytes		1518 bytes	
Tx Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %
10	7,56	24,43	7,76	22,36	7,66	23,42	7,9	21,03	8,08	19,22	7,5	24,96
20	0,2	99	11,96	40,22	12,19	39,04	11,92	40,4	12,1	39,48	12,25	38,76
30	0,02	99,94	16,8	44	16,49	45,04	16,01	46,62	16,39	45,36	16,74	44,2
40	0,01	99,97	0,03	99,92	20,75	48,14	20,32	49,19	20,87	47,83	20,6	48,5
50	0,01	99,98	0,03	99,95	24,96	50,08	24,54	50,91	25,23	49,53	24,52	50,96
60	0,01	99,99	0,02	99,96	0,17	99,71	28,96	51,74	29,8	50,33	29,03	51,62
70	0,01	99,99	0,02	99,97	0,02	99,97	33,26	52,49	34,25	51,08	33,79	51,73
80	0,01	99,99	0,02	99,98	0,05	99,94	37,7	52,87	38,91	51,36	37,54	53,08
90	0,01	99,99	0,01	99,99	0,04	99,96	15,69	82,56	22,59	74,9	22,61	74,88
100	0	100	0,01	99,99	0,03	99,97	7,66	92,34	45,46	54,54	6,24	93,76

Throughput test



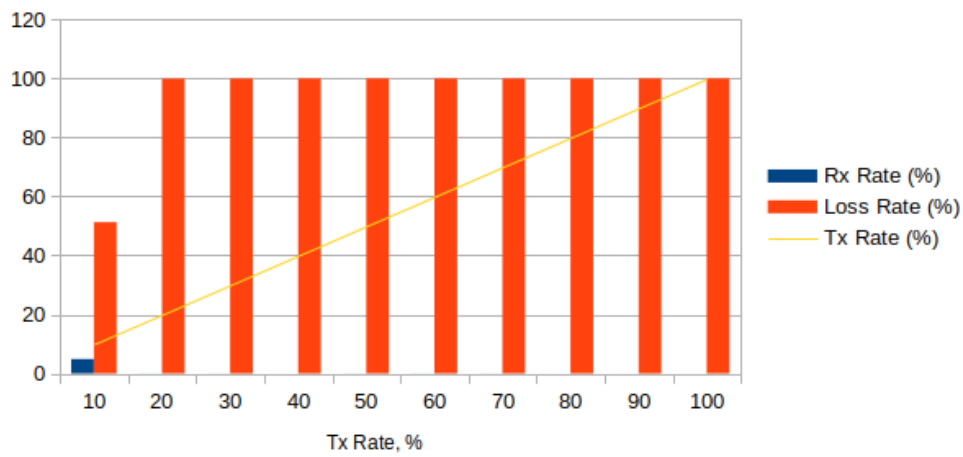
Frame Size, bytes	Tx Rate, %	Tx Rate, b/s	Tx Rate, f/s	Rx Rate, %	Loss Rate, % (frames)	Result
64	0,018	3,19M	4743	0,02	3,47 (4938)	Fail
128	0,027	4,93M	4162	0,03	0 (0)	Pass
256	0,018	3,18M	1438	0,02	0,04 (18)	Fail
512	0,018	3,17M	745	0,02	1,96 (438)	Fail
1024	0,018	3,15M	377	0,02	6,99 (791)	Fail
1280	0,025	4,56M	439	0,03	0 (0)	Pass
1518	0,018	3,14M	255	0,02	2,17 (166)	Fail

1.2. Partial 1:N Mesh Results

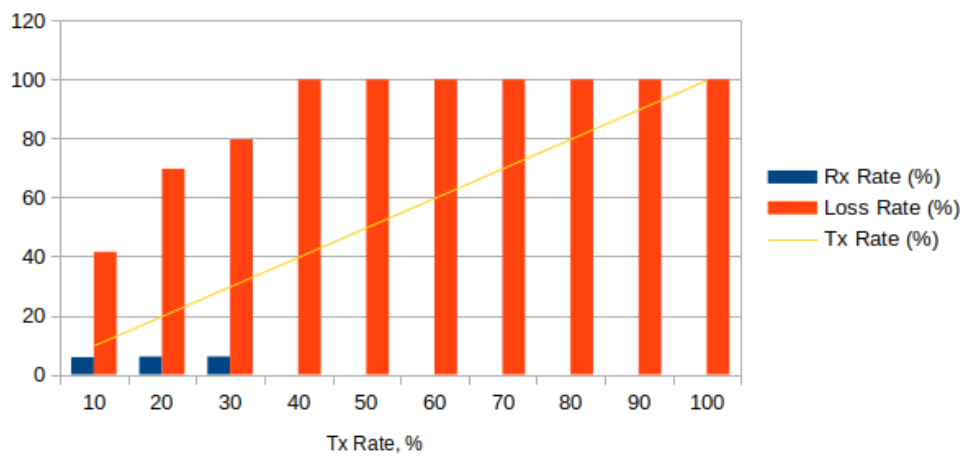


Forwarding test

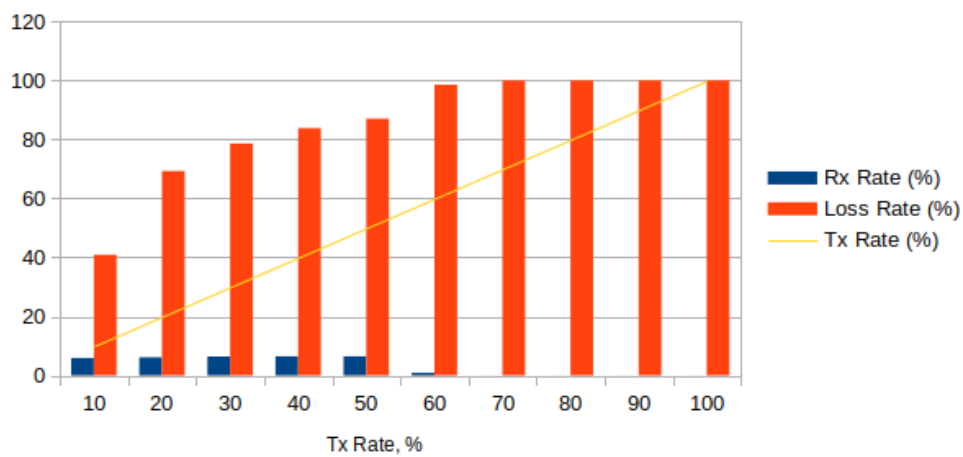
64 bytes Frame Length, 1:N mesh



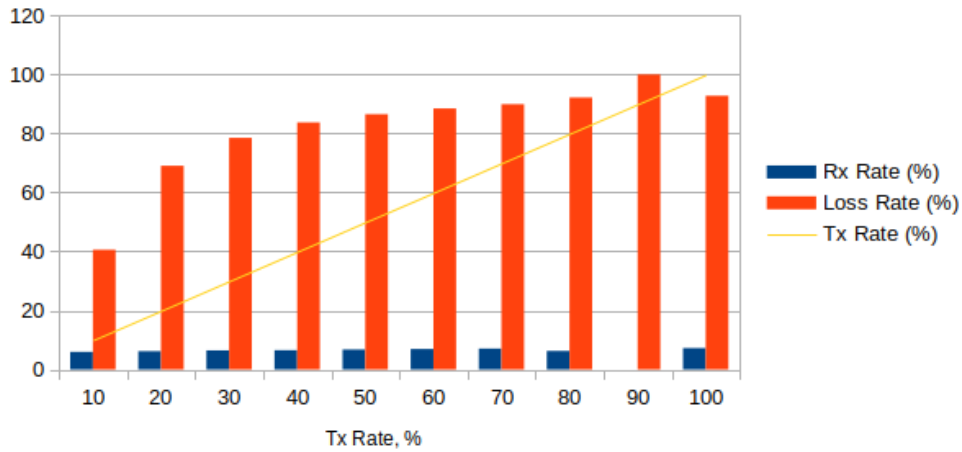
128 bytes Frame Length, 1:N mesh



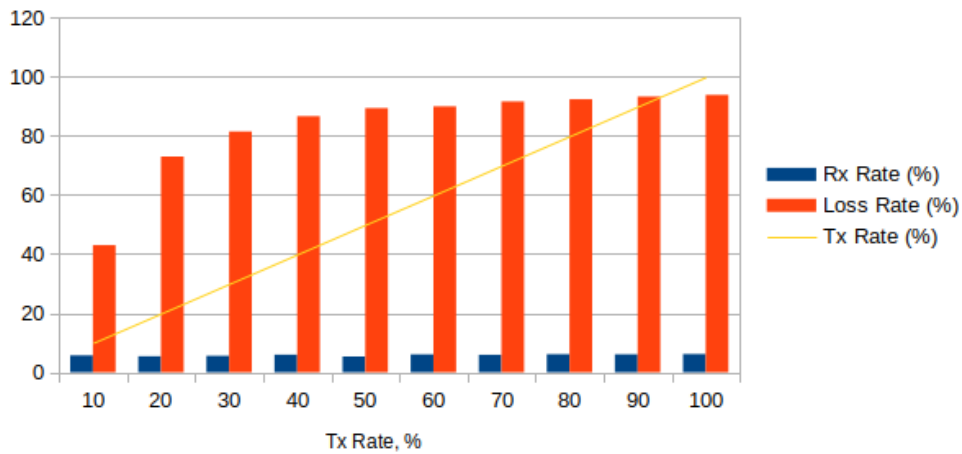
256 bytes Frame Length, 1:N mesh



512 bytes Frame Length, 1:N mesh

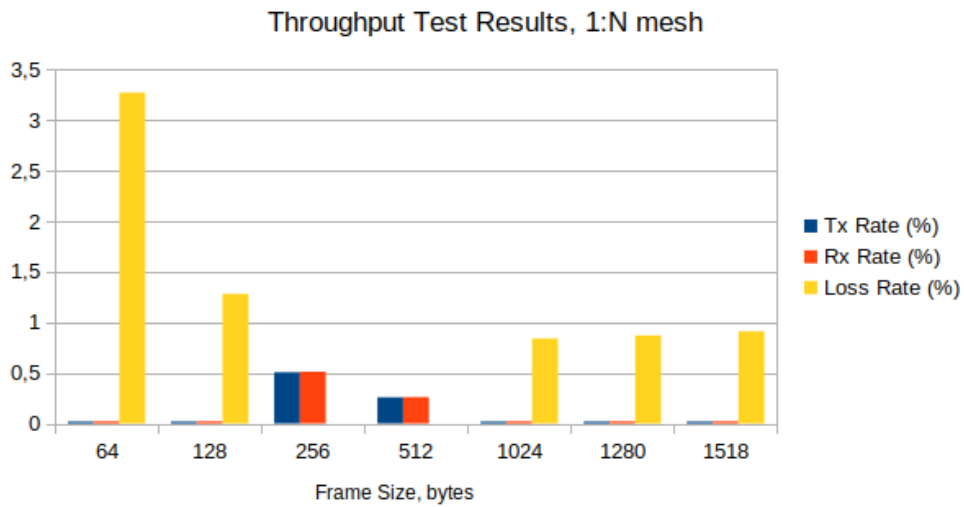


1518 bytes Frame Length, 1:N mesh



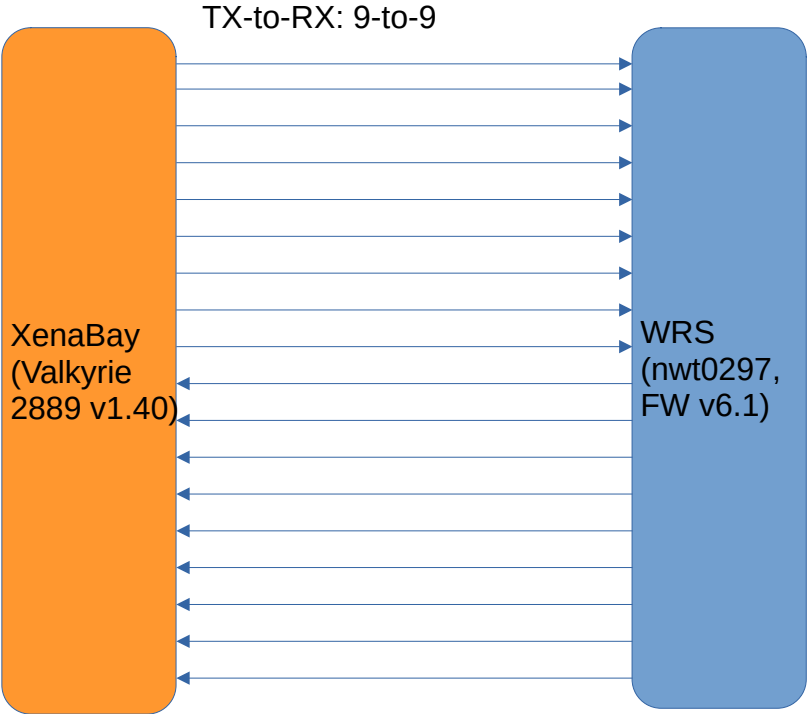
Frame Length	64 bytes		128 bytes		256 bytes		512 bytes		1024 bytes		1518 bytes	
Tx Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %
10	4,87	51,25	5,85	41,54	5,91	40,87	5,94	40,55	4,92	50,77	5,7	43
20	0,02	99,92	6,06	69,7	6,14	69,29	6,19	69,03	6,2	68,98	5,4	72,98
30	0,01	99,96	6,1	79,66	6,41	78,63	6,46	78,47	6,45	78,51	5,56	81,46
40	0	99,99	0,02	99,96	6,47	83,83	6,51	83,72	6,76	83,11	5,92	86,64
50	0,01	99,99	0,01	99,99	6,48	87,04	6,74	86,52	6,87	86,25	5,31	89,37
60	0,01	99,99	0,01	99,98	0,88	98,53	6,92	88,47	6,58	89,04	6,03	89,96
70	0,01	99,99	0	99,99	0,02	99,97	7,06	89,92	6,95	90,07	5,88	91,61
80	0	100	0	100	0,01	99,99	6,26	92,17	6,94	91,33	6,1	92,37
90	0	100	0,01	99,99	0,02	99,98	0	100	6,48	92,8	6,05	93,28
100	0	100	0,01	99,99	0,01	99,99	7,23	92,77	0	100	6,15	93,85

Throughput test



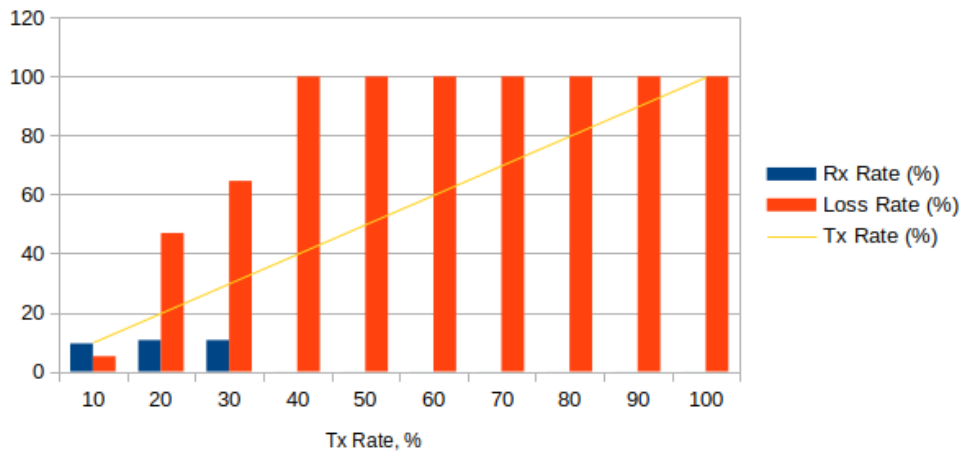
Frame Size, bytes	Tx Rate, %	Tx Rate, b/s	Tx Rate, f/s	Rx Rate, %	Loss Rate, % (frames)	Result
64	0,018	3,19M	4750	0,02	3,24 (4620)	Fail
128	0,018	3,19M	2696	0,02	1,28 (1036)	Fail
256	0,505	90,9M	41168	0,51	0 (0)	Pass
512	0,258	46,36M	10892	0,26	0 (0)	Pass
1024	0,018	3,19M	382	0,02	0,84 (96)	Fail
1280	0,018	3,19M	307	0,03	0,87 (80)	Fail
1518	0,018	3,19M	259	0,02	0,91 (71)	Fail

1.3. Partial N:N Mesh Results

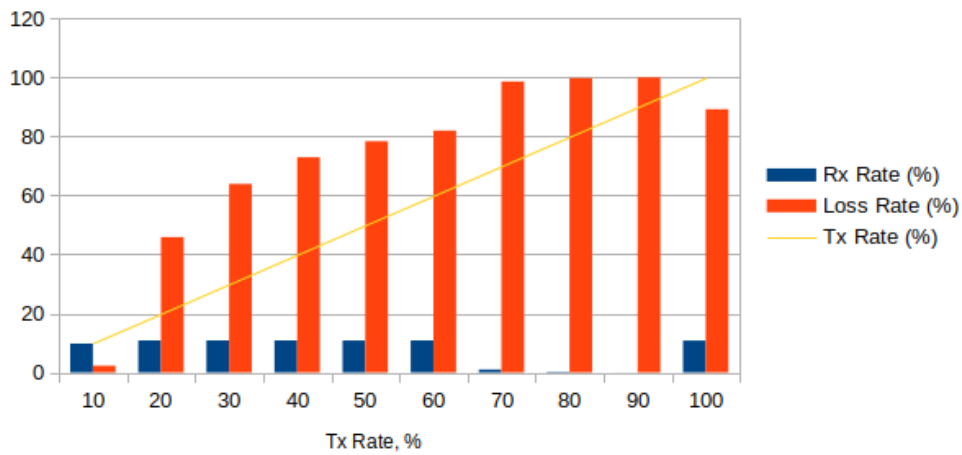


Forwarding test

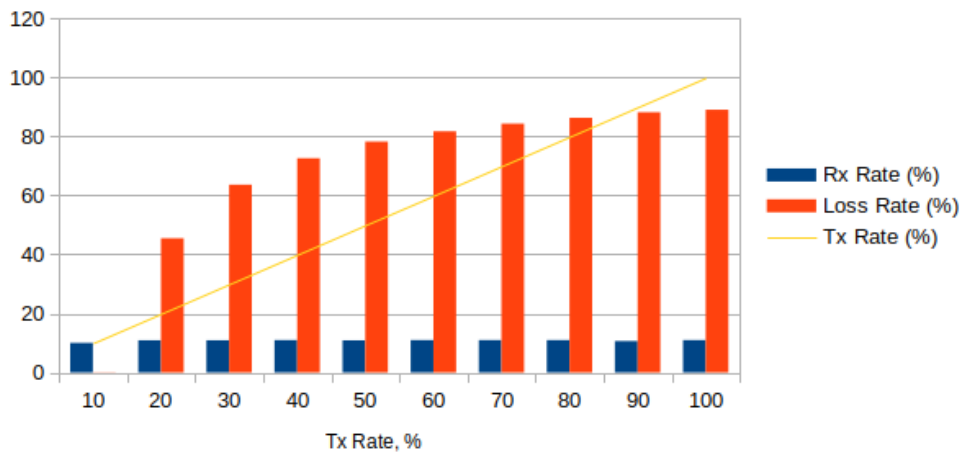
64 bytes Frame Length, N:N mesh



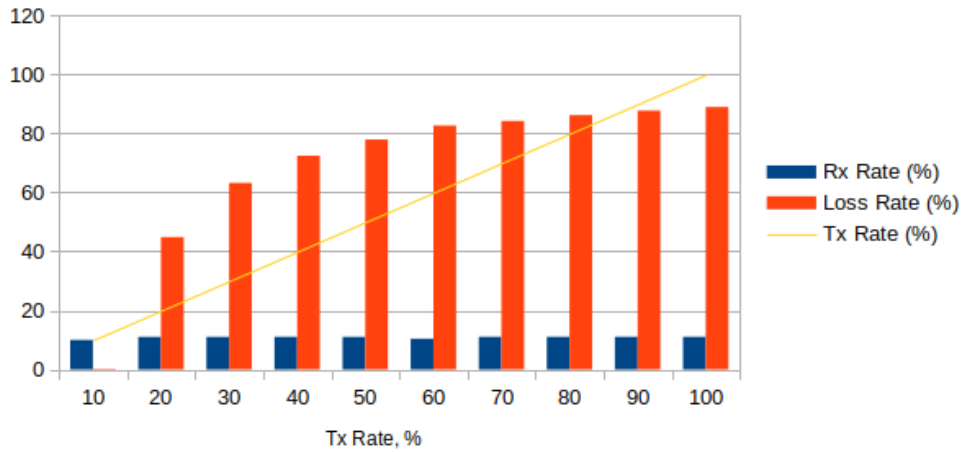
128 bytes Frame Length, N:N mesh



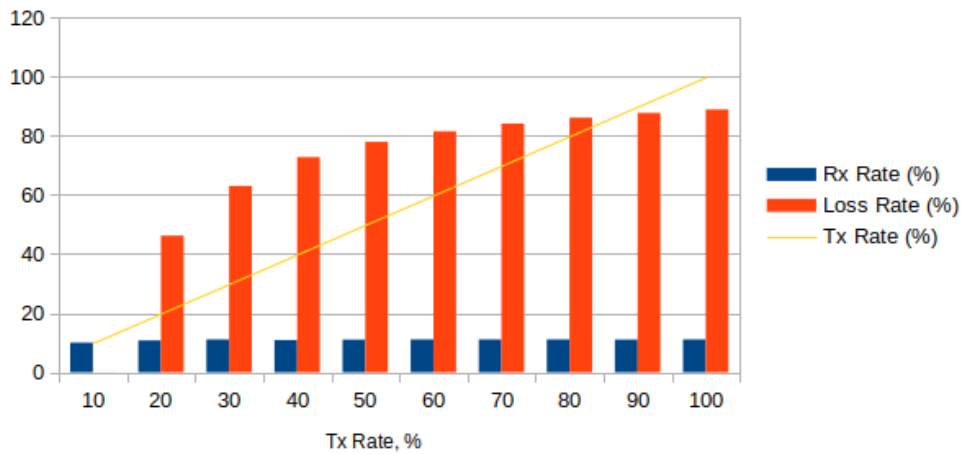
256 bytes Frame Length, N:N mesh



512 bytes Frame Length, N:N mesh

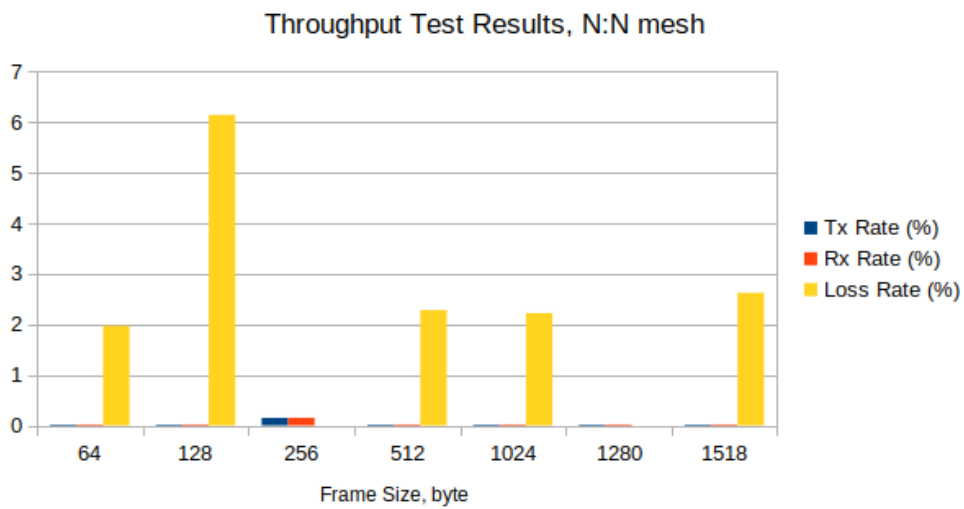


1518 bytes Frame Length, N:N mesh



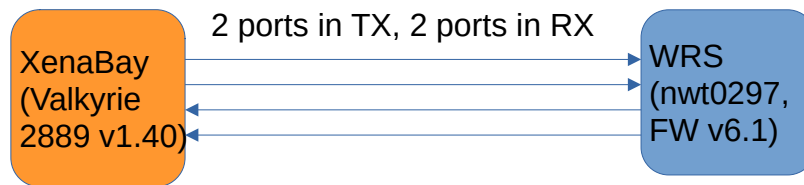
	Frame Length, bytes											
	64		128		256		512		1024		1518	
Tx Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %
10	9,48	5,15	9,77	2,26	9,99	0,08	9,98	0,22	9,74	2,59	10	0,03
20	10,62	46,92	10,83	45,86	10,91	45,46	11,03	44,84	11,02	44,92	10,73	46,22
30	10,62	64,59	10,83	63,92	10,91	63,64	11,03	63,22	10,85	63,85	11,09	63,04
40	0,02	99,96	10,83	72,93	10,96	72,6	11,04	72,41	11,08	72,31	10,89	72,79
50	0,01	99,97	10,82	78,35	10,88	78,25	11,03	77,93	10,79	78,42	11,05	77,93
60	0,01	99,98	10,83	81,96	10,96	81,73	10,39	82,68	10,96	81,74	11,06	81,52
70	0,01	99,99	0,97	98,61	10,96	84,34	11,04	84,23	11,08	84,17	11,09	84,15
80	0,01	99,99	0,19	99,76	10,96	86,31	11,04	86,2	11,05	86,19	11,09	86,13
90	0,01	99,99	0,02	99,98	10,62	88,2	11,04	87,74	11,08	87,69	11,07	87,73
100	0,01	99,99	10,8	89,2	10,96	89,04	11,05	88,95	11,07	88,93	11,09	88,91

Throughput test



Frame Size, bytes	Tx Rate, %	Tx Rate, b/s	Tx Rate, f/s	Rx Rate, %	Loss Rate, % (frames)	Result
64	0,018	1,59M	2373	0,02	1,97 (1404)	Fail
128	0,018	1,6M	1347	0,02	6,14 (2482)	Fail
256	0,149	13,43M	6080	0,15	0 (0)	Pass
512	0,018	1,59M	373	0,02	2,28 (255)	Fail
1024	0,018	1,58M	189	0,02	2,22 (126)	Fail
1280	0,018	1,57M	151	0,02	0 (0)	Pass
1518	0,018	1,59M	130	0,02	2,62 (102)	Fail

1.4. Congestion Control Results

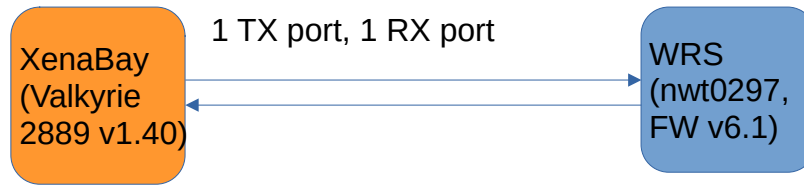


Frame Size	Tx Rate, %	Tx Frames	UC-Port: Tx	UC-Port: Rx	UC-Port: Loss, %	C-Port: Tx	C-Port: Rx	C-Port: Loss, %	Result
64	100	89285714	22321429	22321429	0	66964285	42621994	36,35	Pass
128	100	50675676	12668919	12668919	0	38006757	24672462	35,08	Pass
256	100	27173914	6793479	6793479	0	20380435	13394063	34,28	Pass
512	100	14097746	3524437	3524437	0	10573309	6996705	33,83	Pass
1024	100	7183909	1795978	1795978	0	5387932	3578495	33,58	Pass
1280	100	5769232	1442308	1442308	0	4326924	2875980	33,53	Pass
1518	100	4876464	1219116	1194263	0	3657348	2432097	33,50	Fail

C-Port: Congested Port

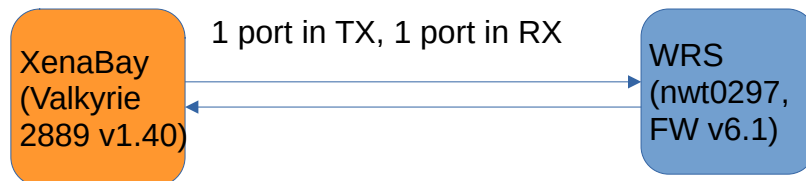
UC-Port: Uncongested Port

1.5. Forward Pressure Results



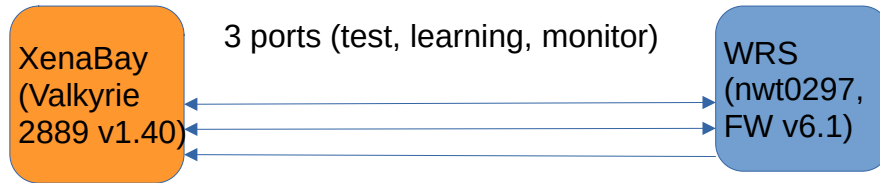
Frame Size, bytes	Tx Frames	Tx max. util., %	Rx Frames	Rx max. util., %	Loss, %	Result
64	45180722	101,205	42613671	95,45	5,68	Pass
128	25510204	100,68	24671105	97,368	3,29	Pass
256	13636363	100,364	13392910	98,571	1,79	Pass
512	7062146	100,188	6996323	99,254	0,93	Pass
1024	3595397	100,096	3578303	99,618	0,48	Pass
1280	2886836	100,077	2875826	99,693	0,38	Pass
1518	2439817	100,065	2431964	99,74	0,32	Pass

1.6. Maximum Forwarding Rate Results



Frame Size, bytes	Tx Rate, %	Tx Rate, f/s	Tx Frames	Rx Frames	Loss, % (calculated)	Result
64	100	1488,1K	44642857	42613750	4,54	Pass
128	100	844,6K	25337837	24671132	2,63	Pass
256	100	452,9K	13586956	13392932	1,43	Pass
512	100	234,9K	7048872	6996338	0,75	Pass
1024	100	119,7K	3591954	3578310	0,38	Pass
1280	100	96,1K	2884615	2875831	0,304	Pass
1518	100	81,3K	2438231	2431968	0,25	Pass

1.7. Address Caching Capacity and Learning Rate Results



Address Caching Capacity (Learning Rate=20 Frames/s)

Frame Size, bytes	Address Count	Test Port Tx Frames	Learn Port Rx Frames	Monitor Port Rx Frames	Result
64	1500	1500	1500	0	Pass
128	1500	1500	1500	0	Pass
256	1469	1469	1469	0	Pass
512	982	982	982	0	Pass
1024	1225	1225	1225	0	Pass
1280	1469	1469	1469	0	Pass
1518	769	769	769	0	Pass

Address Learning Rate, frame/s

Frame size, byte Address count	64	128	256	512	1024	1280	1518
100	80	80	80	80	80	40	80
612	80	80	80	40	40	40	40
1124	40	80	20		20	20	
1500	80	40					
1469			20			20	
982				20			
1225					20		
769							20

Issue (23.10.2023): RTU routing table keeps the part of dynamic entries (check output of 'rtu_stat'). Many of them have even aging value of '0'. Attempts to remove them manually with 'rtu_stat remove all <port> 1' fails. It looks like that there is a problem with MAC aging.

Considering the MAC aging issue, another option is selected for address learning reset (**switching test and learning port roles between iterations**) and the test is repeated with following settings:

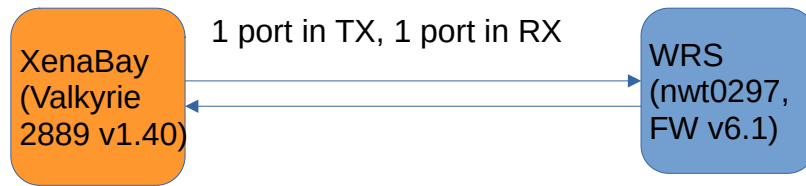
- frame size: 512 bytes
- learning rate: 20 frame/s

In this setup, **test is passed** learning up to 1439 addresses: switch forwards the test packets (100, 1074, #1561, 1317, 1439) properly in all iterations except those with critical/high number of packets (1561). For test report refer to xena2889-report-20231023-195822.pdf.

If the aging time of 350 seconds (300 seconds for WR switches by default) is chosen for the reset condition, then **test is failed** again. 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

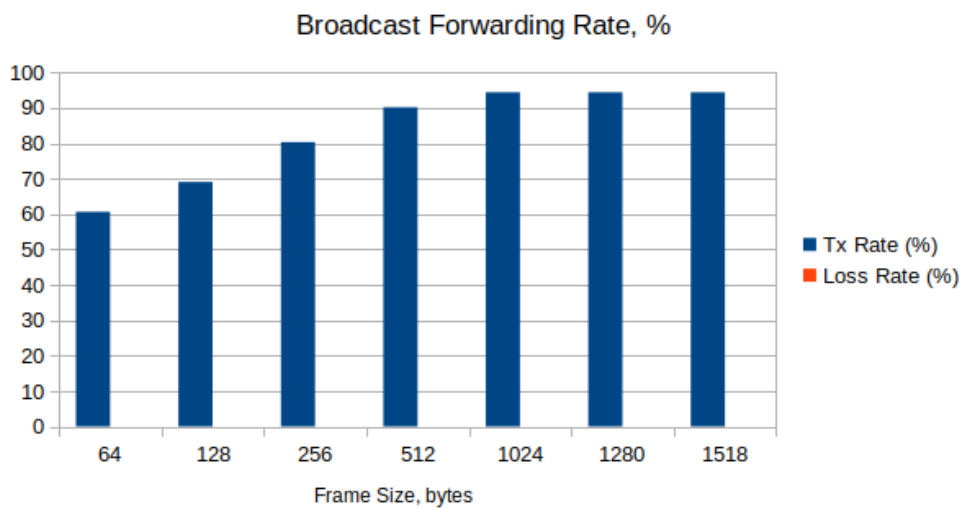
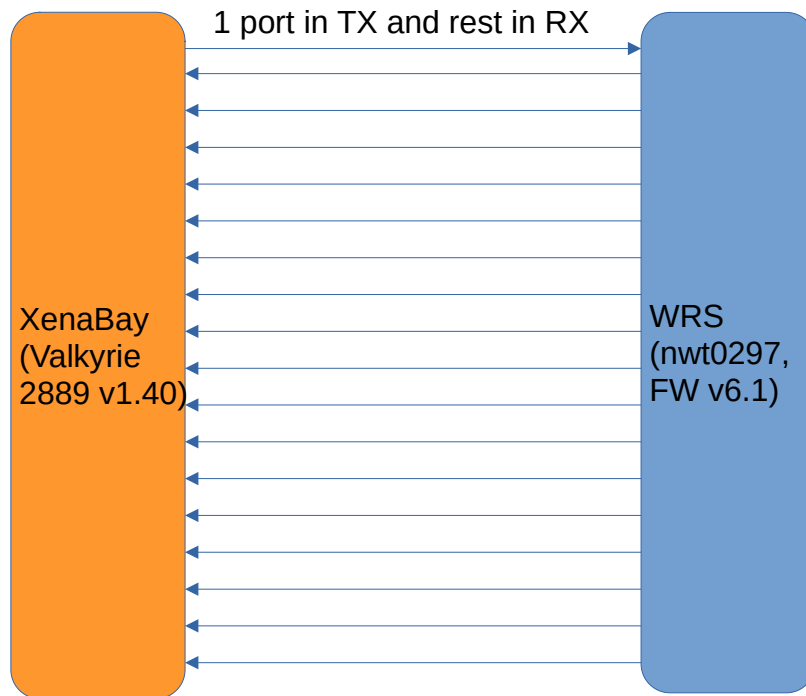
test packets (1317, 1195, ..., 1075, 1074). The test is failed because the switch floods even with the same number of packets (1074), with which no flooding was happened in previous iteration. For test details refer to xena2889-report-20231023-194401.pdf.

1.8. Errored Frames Filtering Results



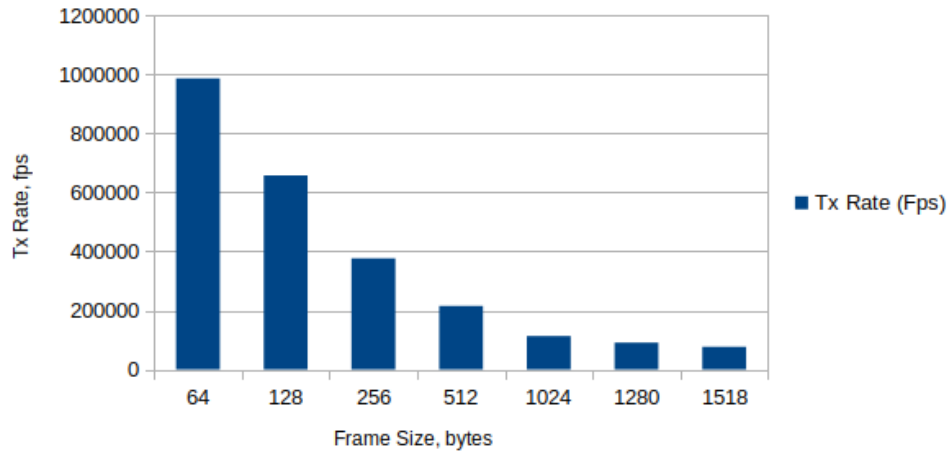
Tx Rate, %	Tx Frames	Rx Frames	Tx Valid	Rx Valid	Tx Over size	Rx Over size	Tx Under size	Rx Under size	Tx FCS Error	Rx FCS Error	Result
10	1741375	1741290	154130	154130	81221	81221	1506024	1505939	58	0	Fail
20	3482752	3482617	308261	308261	162443	162443	3012048	3011913	58	0	Fail
30	5224128	5223881	462392	462392	243664	243664	4518072	4517825	58	0	Fail
40	6965430	6965089	616522	616522	324812	324812	6024096	6023755	58	0	Fail
50	8706880	8706482	770653	770653	406107	406107	7530120	7529722	58	0	Fail
60	10448257	10447811	924784	924784	487329	487329	9036144	9035698	58	0	Fail
70	12188912	12187983	1078864	1078864	568530	568530	10541518	10540589	58	0	Fail
80	13931001	13929961	1233045	1233045	649764	649764	12048192	12047152	58	0	Fail
90	15672386	15671187	1387176	1387176	730994	730994	13554216	13553017	58	0	Fail
100	17413762	13740596	1541307	1477904	812215	632575	15060240	11630117	58	0	Fail

1.9. Broadcast Forwarding Results



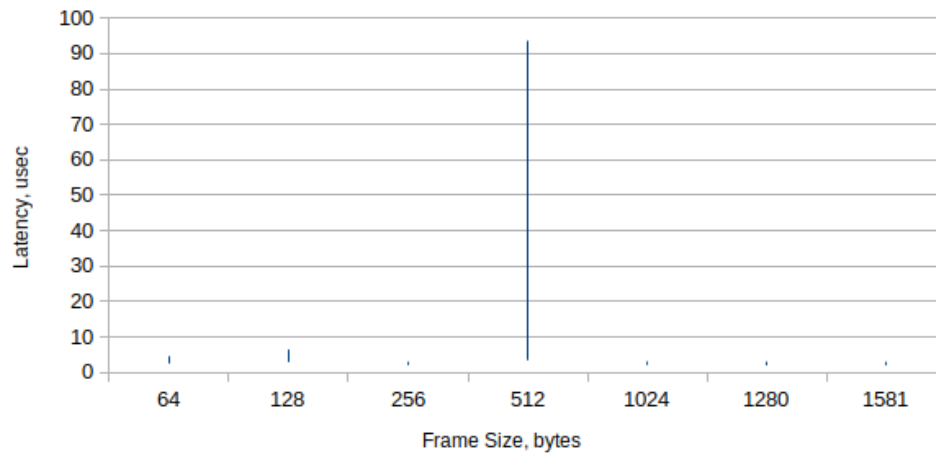
Frame Size, bytes	Tx Rate, %	Loss Rate, %	Loss Frames	Result
64	60,62	0	0	Pass
128	69,06	0	0	Pass
256	80,31	0	0	Pass
512	90,15	0	0	Pass
1024	94,37	0	0	Pass
1280	94,37	0	0	Pass
1518	94,37	0	0	Pass

Throughput Broadcast Forwarding



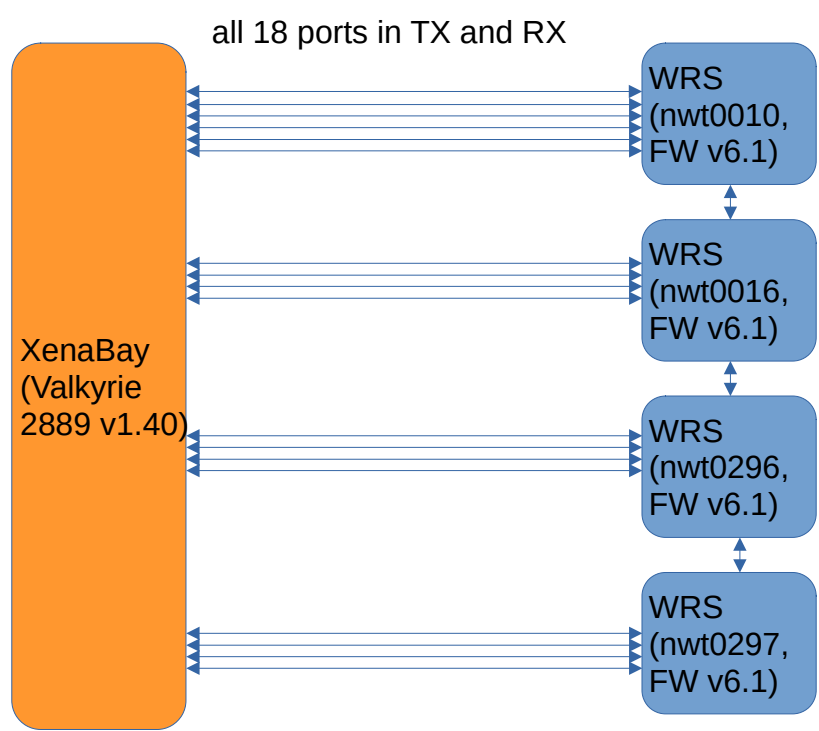
Frame Size, bytes	Tx Rate (Fps)
64	986377
128	657530
256	376472
512	215137
1024	112997
1280	90725
1518	76703

Average Latency, usec



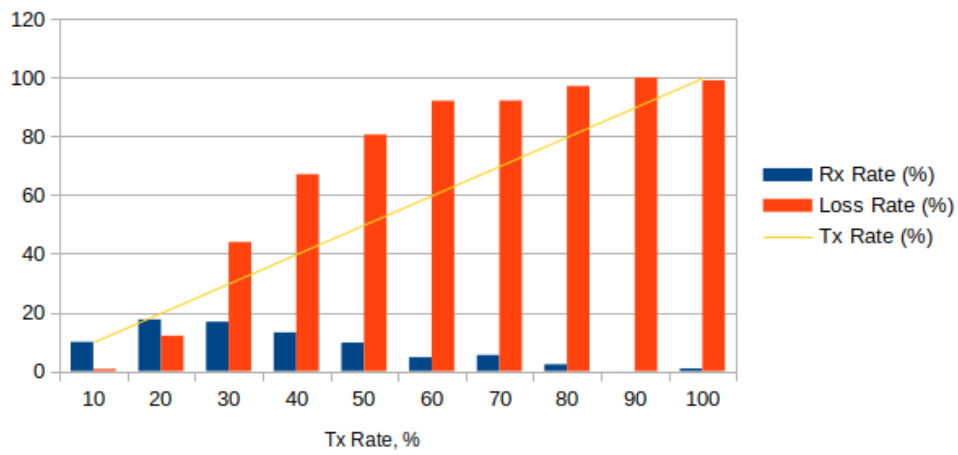
Frame Size, bytes	Latency, usec			Jitter, usec		
	Average	Min	Max	Average	Min	Max
64	2,48-4,52	1,29-2,28	6,84-11,29	0,003-0,011	0	2,23-2,74
128	2,88-6,41	1,78-2,75	6,93-12,07	0,002	0	2,02-2,35
256	2,03-2,97	1,77-2,74	4,32-6,54	0,008-0,01	0	2,11-2,52
512	3,41-93,63	1,78-2,96	8,06-216,34	0,002	0	2,06-2,33
1024	2,07-3,03	1,82-2,76	4,41-5,36	0,003-0,004	0	2,21-2,5
1280	1,99-2,97	1,78-2,75	4,21-5,37	0,004-0,006	0	2,14-2,57
1518	1,99-2,97	1,78-2,73	4,12-5,33	0,002-0,003	0	2,14-2,5

2.1. Full Mesh Results, 4 layers

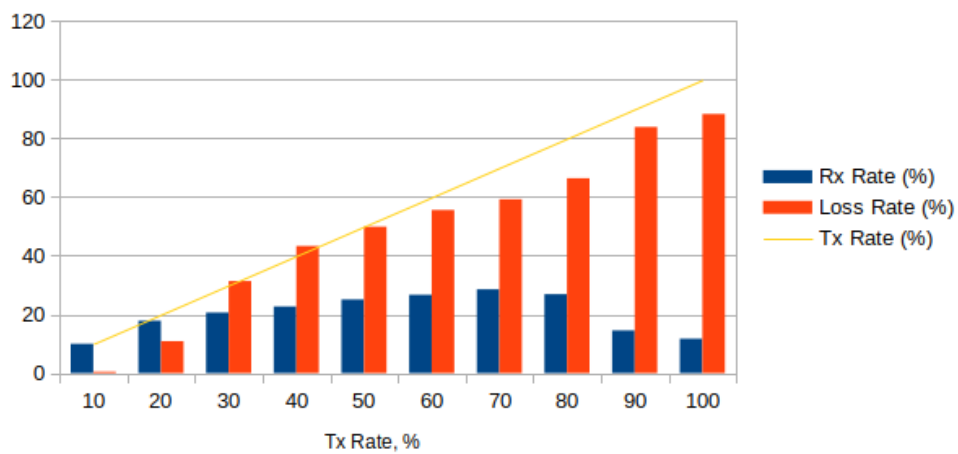


Forwarding test

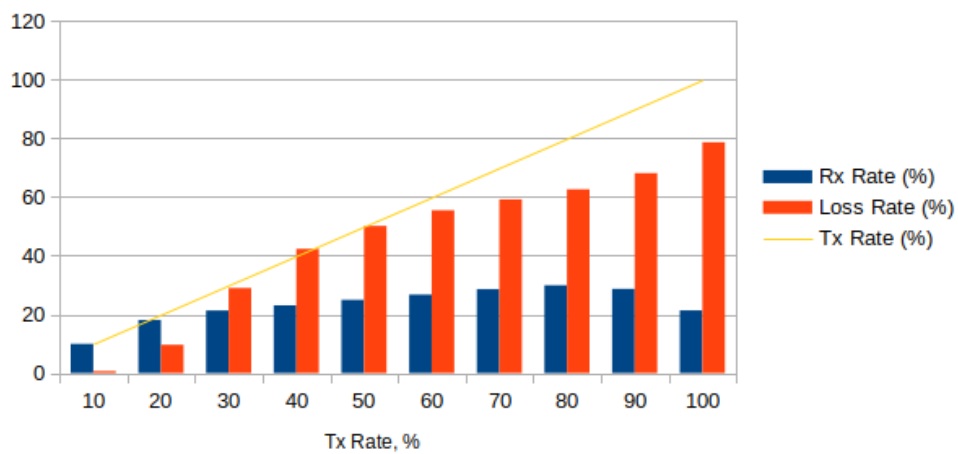
64 bytes Frame Length, full mesh (4 layers)



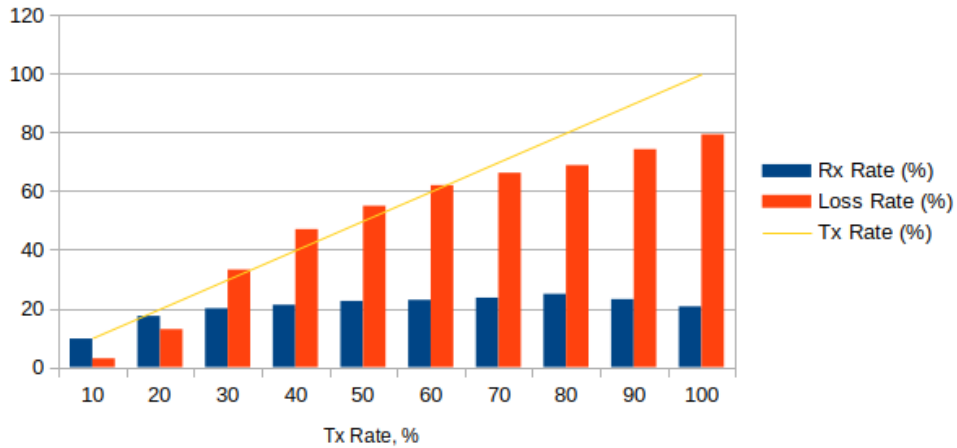
128 bytes Frame Length, full mesh (4 layers)



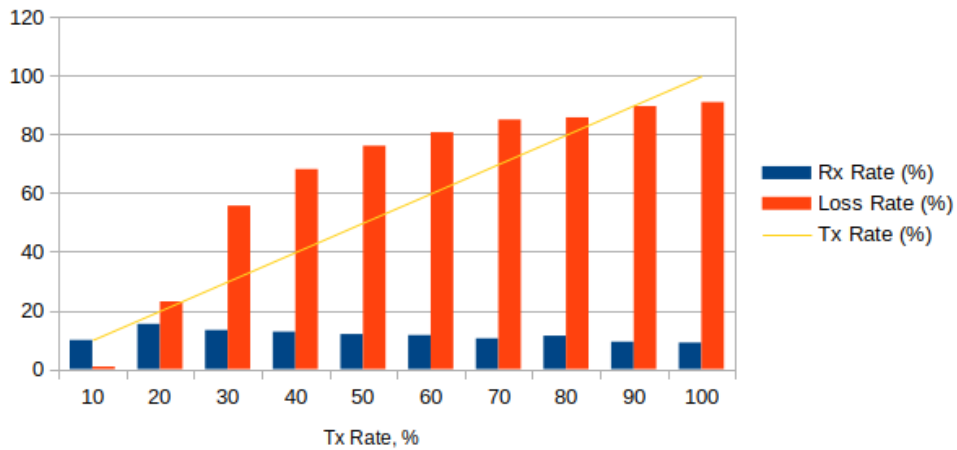
256 bytes Frame Length, full mesh (4 layers)



1024 bytes Frame Length, full mesh (4 layers)

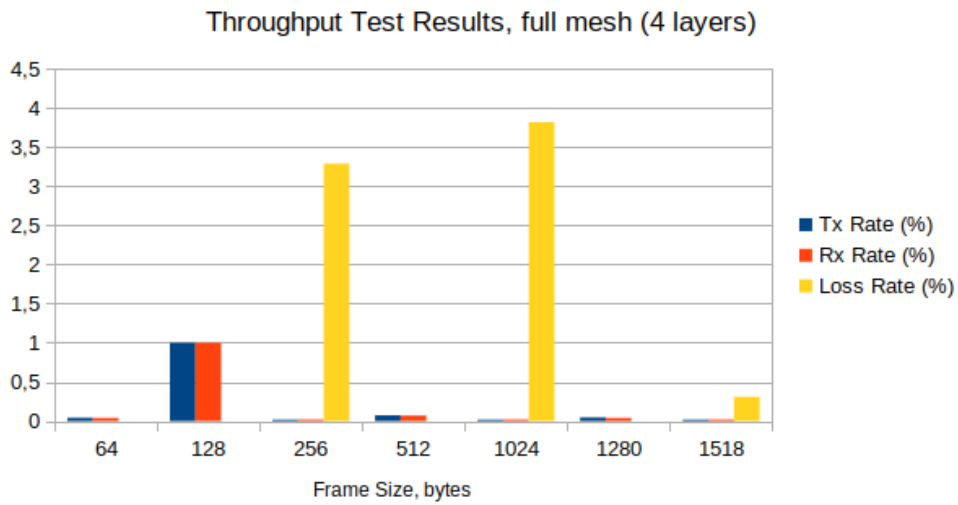


1518 bytes Frame Length, full mesh (4 layers)



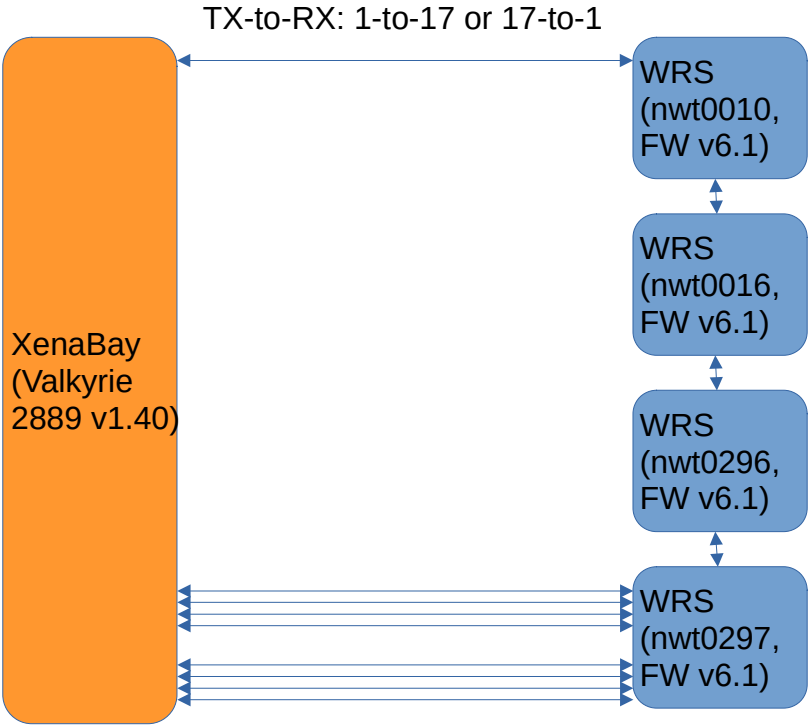
Frame Length	64 bytes		128 bytes		256 bytes		512 bytes		1024 bytes		1518 bytes	
Tx Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %
10	9,93	0,69	9,95	0,48	9,93	0,67	9,88	1,21	9,7	2,96	9,91	0,86
20	17,59	12,03	17,83	10,87	18,08	9,62	18,03	9,86	17,42	12,91	15,39	23,05
30	16,82	43,95	20,6	31,35	21,31	28,98	20,97	30,09	20,03	33,23	13,3	55,68
40	13,17	67,08	22,68	43,29	23,08	42,31	23,16	42,1	21,23	47	12,74	68,15
50	9,7	80,61	25,06	49,88	24,94	50,12	24,89	50,22	22,53	54,95	11,94	76,13
60	4,72	92,13	26,66	55,57	26,73	55,45	26,17	56,39	22,91	62	11,57	80,72
70	5,47	92,18	28,54	59,23	28,57	59,19	28,9	58,71	23,65	66,22	10,47	85,05
80	2,29	97,14	26,87	66,42	29,9	62,62	30,06	62,42	24,95	68,82	11,37	85,78
90	0,01	99,98	14,52	83,87	28,67	68,14	23,4	74	23,16	74,26	9,33	89,63
100	0,89	99,11	11,7	88,3	21,35	78,65	28,11	71,89	20,66	79,34	9,01	90,99

Throughput test



Frame Size, bytes	Tx Rate, %	Tx Rate, b/s	Tx Rate, f/s	Rx Rate, %	Loss Rate, % (frames)	Result
64	0,041	3,19M	4743	0,04	0 (0)	Pass
128	1	1,31G	1,1M	1	0 (0)	Pass
256	0,018	90,9M	41K	0,02	3,29 (1420)	Fail
512	0,073	91,21M	21K	0,07	0 (0)	Pass
1024	0,018	3,15M	377	0,02	3,82 (432)	Fail
1280	0,045	3,18M	306	0,04	0 (0)	Pass
1518	0,018	3,14M	255	0,02	0,31 (24)	Fail

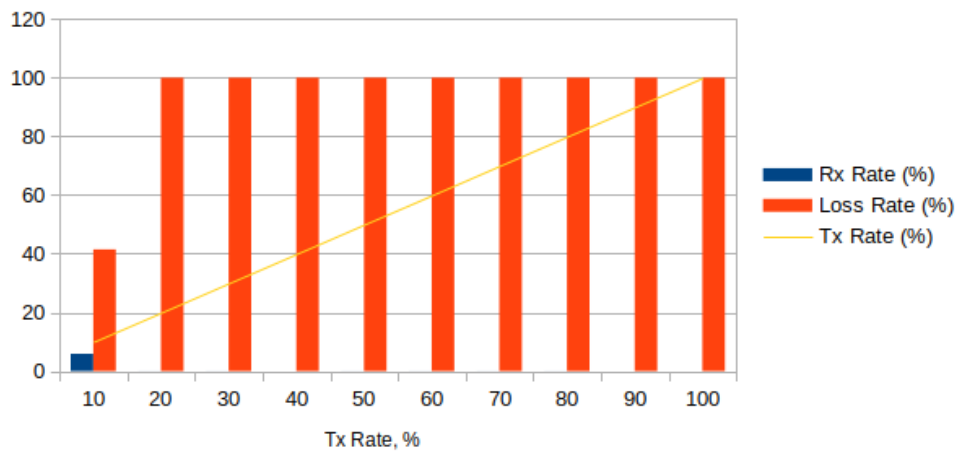
2.2. Partial 1:N Mesh Results¹, 4 layers



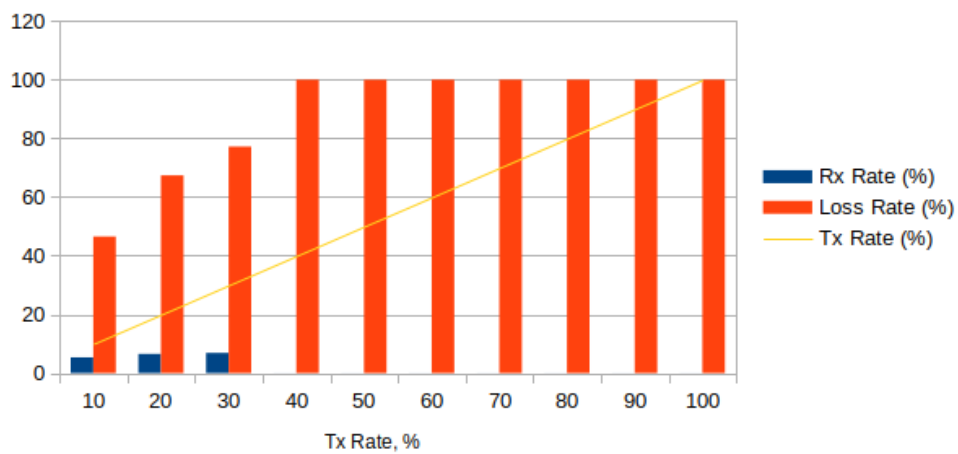
1 Source: xena2889-report-20231114-122401.pdf

Forwarding test

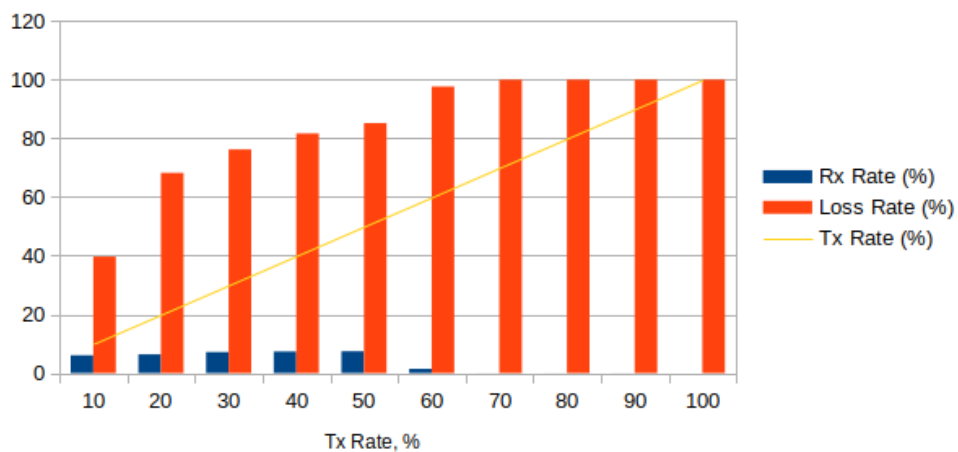
64 bytes Frame Length, 1:N mesh (4 layers)



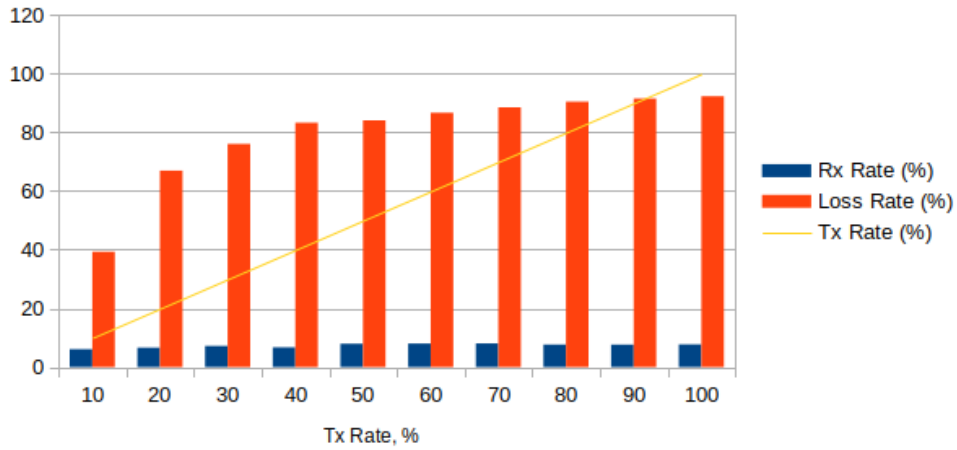
128 bytes Frame Length, 1:N mesh (4 layers)



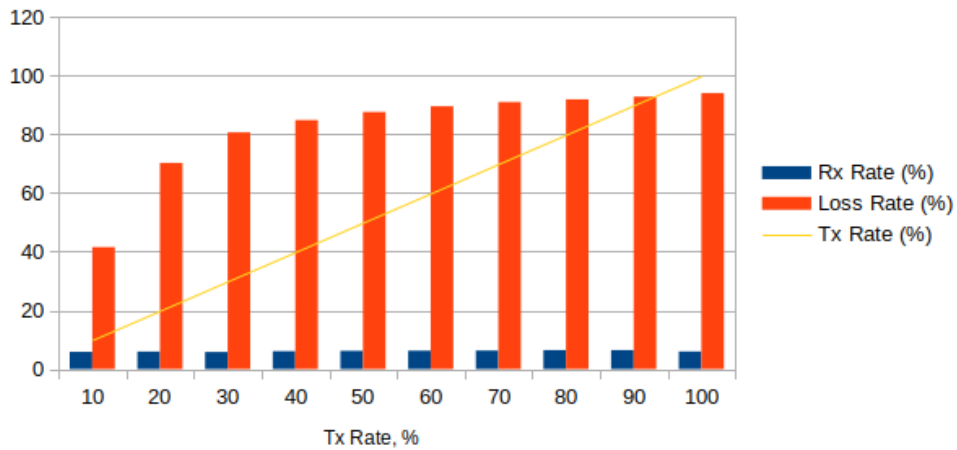
256 bytes Frame Length, 1:N mesh (4 layers)



512 bytes Frame Length, 1:N mesh (4 layers)

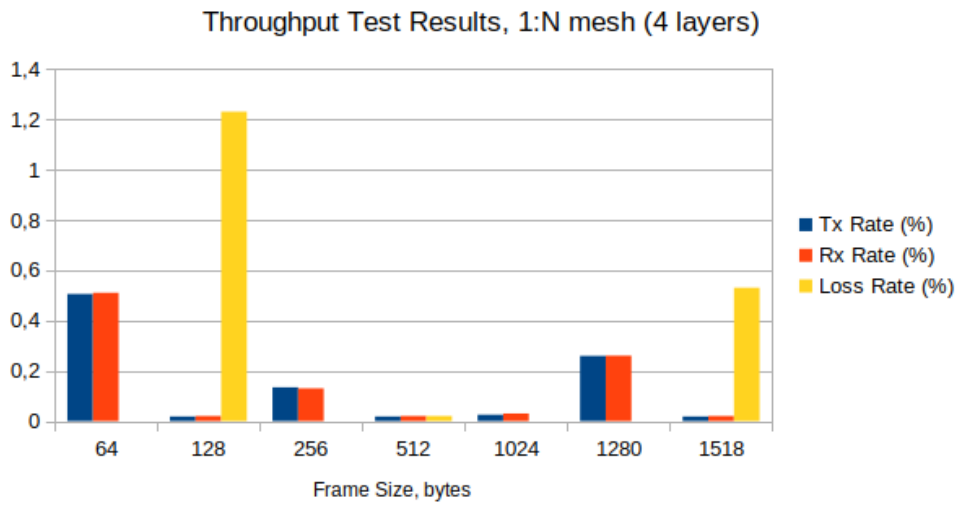


1518 bytes Frame Length, 1:N mesh (4 layers)



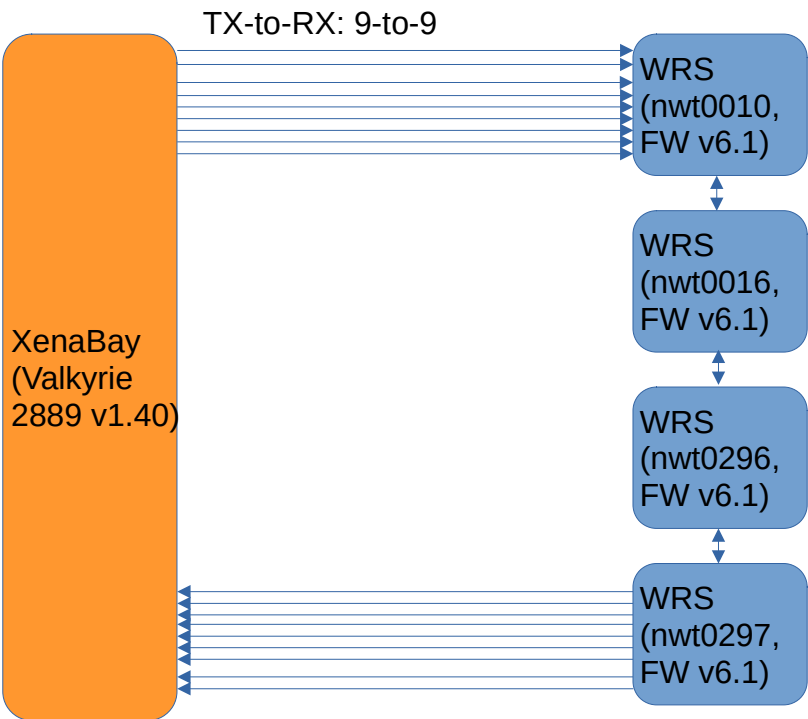
Frame Length	64 bytes		128 bytes		256 bytes		512 bytes		1024 bytes		1518 bytes	
Tx Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %
10	5,83	41,67	5,94	40,64	6,02	39,82	6,03	39,65	6,06	39,37	5,85	41,49
20	6,27	68,66	6,35	68,25	6,38	68,11	6,46	67,7	5,83	70,84	5,87	70,66
30	6,5	78,32	5,25	82,49	6,76	77,48	6,31	78,96	6,21	79,31	5,41	81,97
40	6,57	83,57	6,91	82,73	6,97	82,56	7,02	82,44	7,02	82,45	5,83	85,41
50	0,01	99,99	7,09	85,81	7,37	85,27	7,3	85,41	7,3	85,4	5,9	88,2
60	0,01	99,98	6,64	88,93	7,08	88,21	7,58	87,36	7,63	87,28	5,79	90,17
70	0,01	99,99	7,65	89,07	7,8	88,86	7,83	88,81	7,26	89,63	5,79	91,73
80	0,02	99,98	7,82	90,23	7,96	90,05	8,09	89,88	7,73	90,34	5,79	92,76
90	0,01	99,99	0,01	99,98	7,71	91,44	7,94	91,18	8,21	90,88	5,74	93,62
100	0,01	99,99	0	100	7,86	92,14	8,06	91,94	8,37	91,63	5,64	94,36

Throughput test



Frame Size, bytes	Tx Rate, %	Tx Rate, b/s	Tx Rate, f/s	Rx Rate, %	Loss Rate, % (frames)	Result
64	0,505	90,9M	135K	0,51	0 (0)	Pass
128	0,018	3,19M	2696	0,02	1,23 (991)	Fail
256	0,134	24,07M	11K	0,13	0 (0)	Pass
512	0,018	3,19M	750	0,02	0,02 (5)	Fail
1024	0,025	4,58M	548	0,03	0 (0)	Pass
1280	0,259	46,69M	4490	0,26	0 (0)	Pass
1518	0,018	3,19M	259	0,02	0,53 (41)	Fail

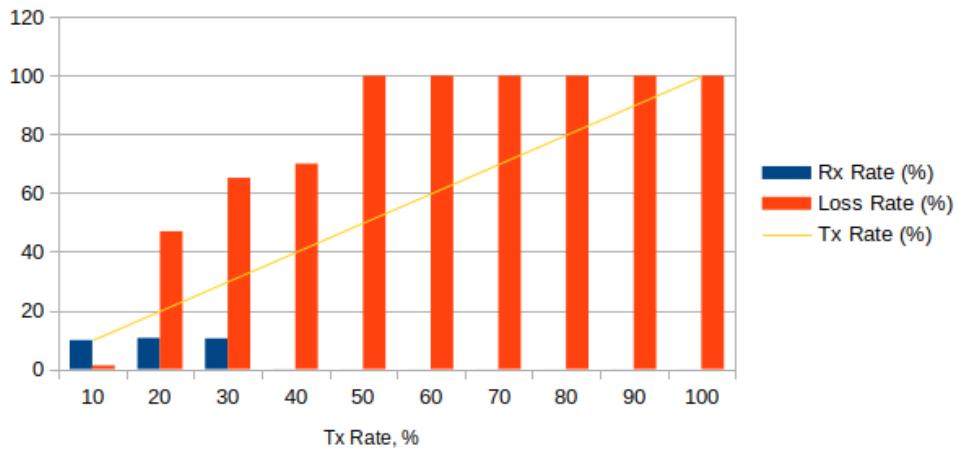
2.3. Partial N:N Mesh Results², 4 layers



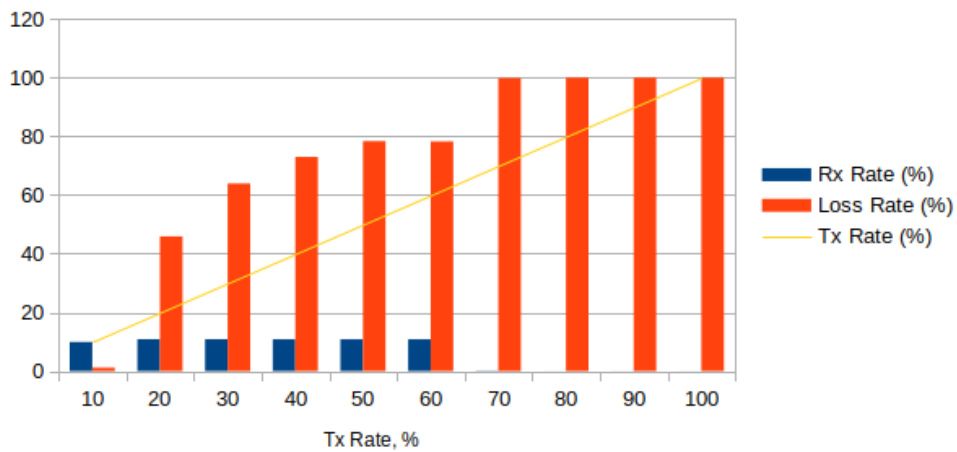
² Source: xena2889-report-20231113-173928.pdf

Forwarding test

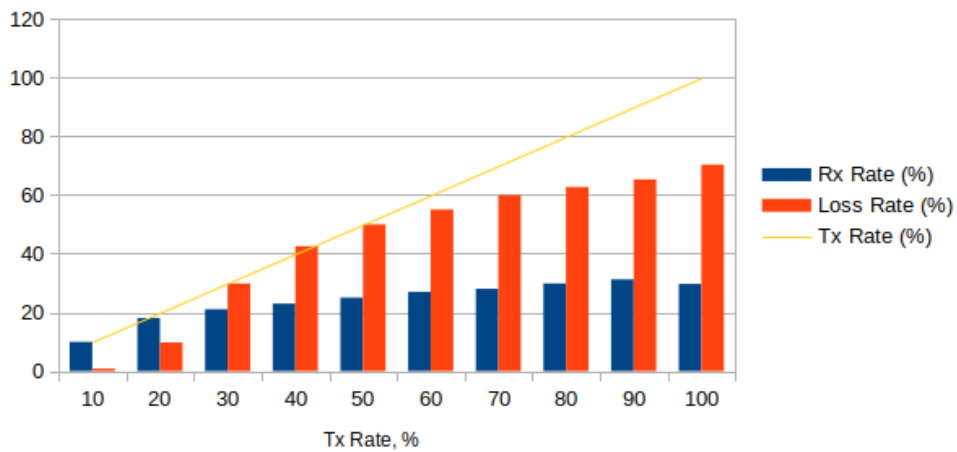
64 bytes Frame Length, N:N mesh (4 layers)



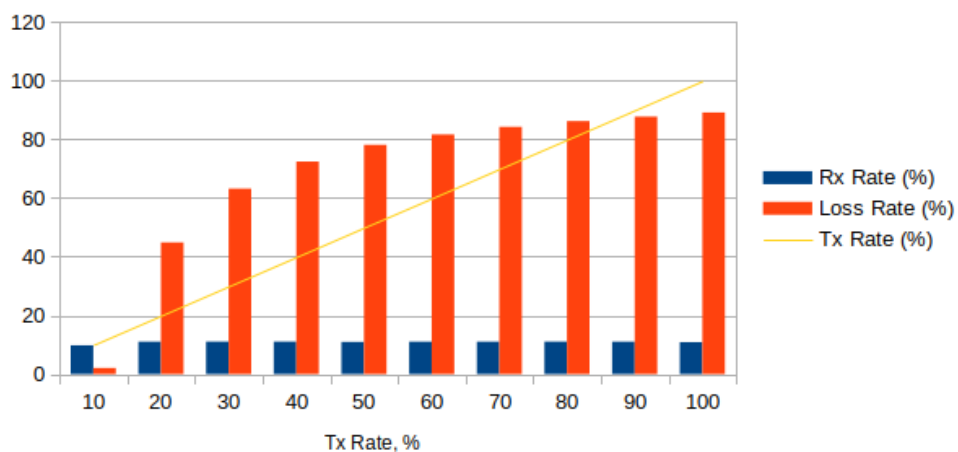
128 bytes Frame Length, N:N mesh (4 layers)



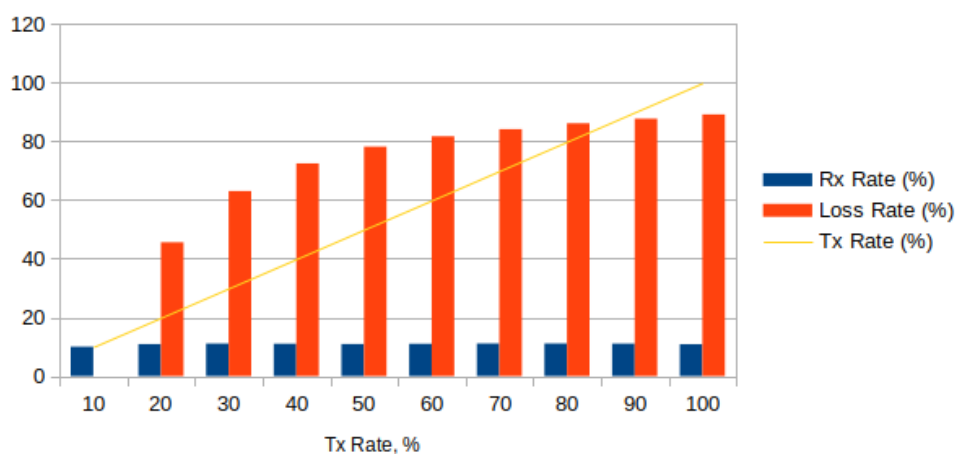
256 bytes Frame Length, full mesh



512 bytes Frame Length, N:N mesh (4 layers)

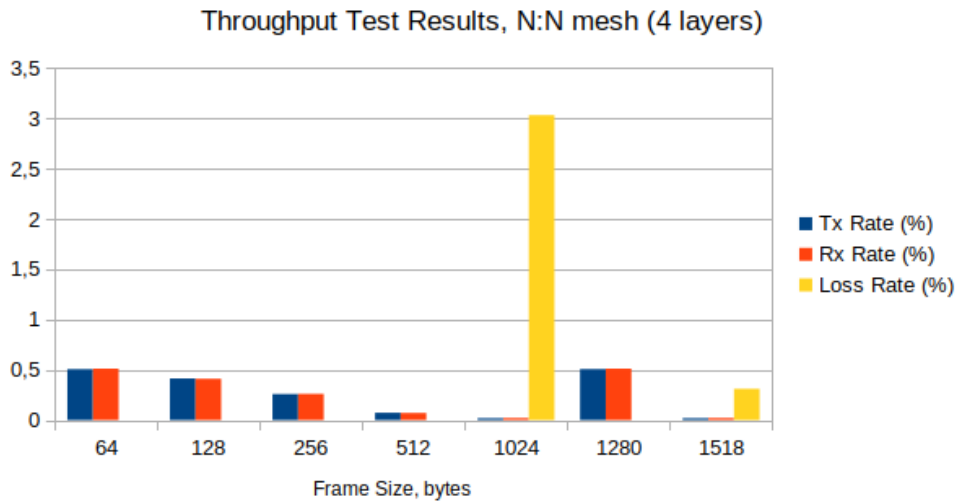


1518 bytes Frame Length, N:N mesh (4 layers)



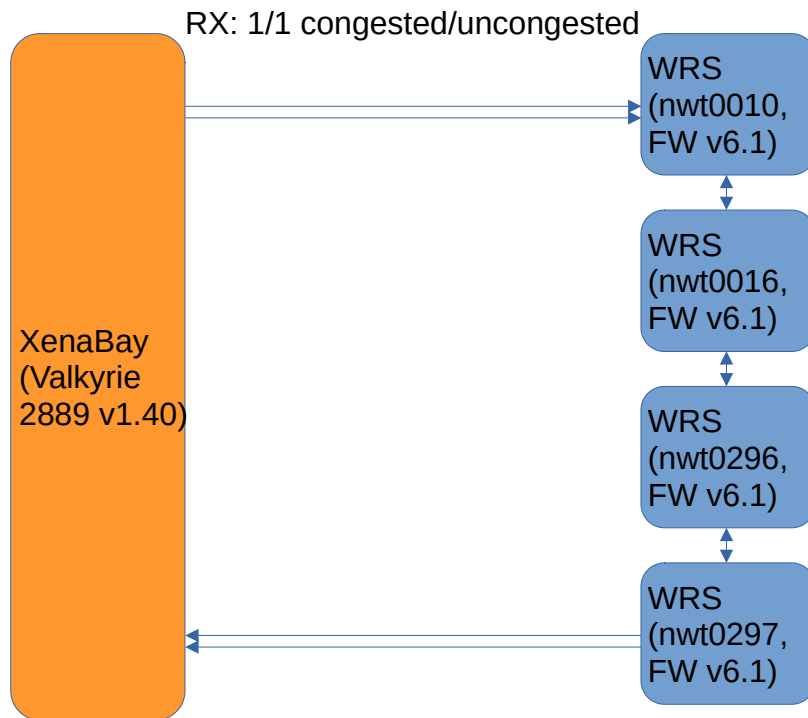
	Frame Length, bytes											
	64		128		256		512		1024		1518	
Tx Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %	Rx Rate, %	Loss Rate, %
10	9,88	1,22	9,89	1,14	9,99	0,07	9,79	2,07	9,97	0,29	10	0
20	10,61	46,95	10,83	45,87	10,96	45,22	11,03	44,83	10,88	45,59	10,88	45,58
30	10,45	65,17	10,83	63,91	10,96	63,46	11,04	63,21	11,08	63,08	11,06	63,05
40	0,03	69,99	10,81	72,98	10,96	72,6	11,04	72,41	11,08	72,31	11,01	72,48
50	0,01	99,97	10,82	78,36	10,92	78,17	10,94	78,12	11,08	77,85	10,9	78,19
60	0,01	99,98	10,82	78,25	10,96	81,73	11,02	81,64	11,08	81,54	10,98	81,71
70	0,01	99,99	0,11	99,85	10,96	84,34	11,03	84,24	10,99	84,3	11,09	84,15
80	0,01	99,99	0,01	99,98	10,83	86,46	11,04	86,2	11,08	86,15	11,09	86,14
90	0,01	99,99	0,01	99,99	10,84	87,96	11,03	87,74	10,84	87,95	11,05	87,72
100	0,01	99,99	0,01	99,99	10,96	89,04	10,87	89,13	11,08	88,92	10,83	89,17

Throughput test



Frame Size, bytes	Tx Rate, %	Tx Rate, b/s	Tx Rate, f/s	Rx Rate, %	Loss Rate, % (frames)	Result
64	0,505	45,45M	67,6K	0,51	0 (0)	Pass
128	0,413	37,14M	31,4K	0,41	0 (0)	Pass
256	0,258	23,2M	10,5K	0,26	0 (0)	Pass
512	0,072	6,47M	1520	0,07	0 (0)	Pass
1024	0,018	1,58M	189	0,02	3,03 (172)	Fail
1280	0,506	45,52M	4377	0,51	0 (0)	Pass
1518	0,018	1,59M	130	0,02	0,31 (12)	Fail

2.4. Congestion Control Results, 4 layers

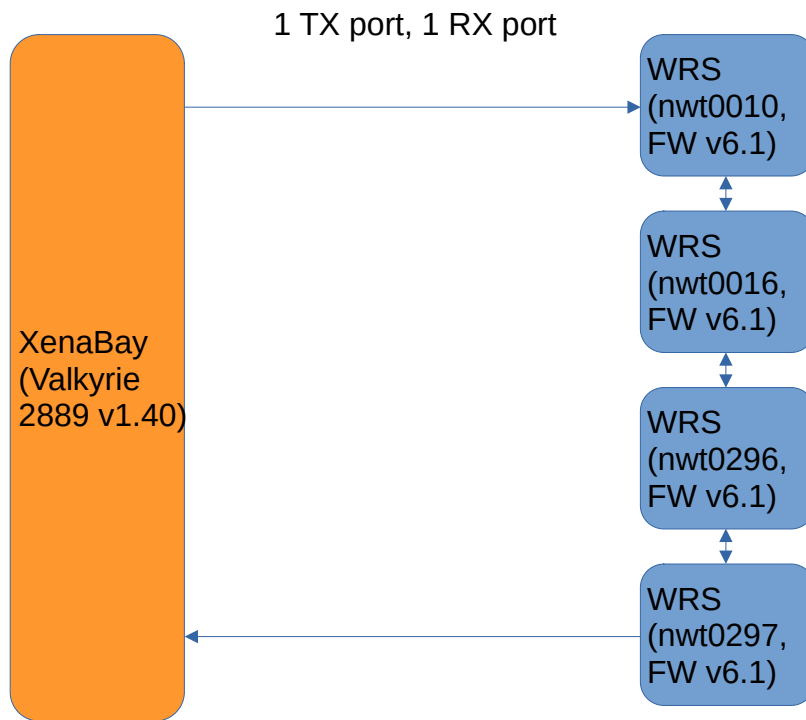


Frame Size	Tx Rate, %	Tx Frames	UC-Port: Tx	UC-Port: Rx	UC-Port: Loss, %	C-Port: Tx	C-Port: Rx	C-Port: Loss, %	Result
64	100	89285715	22321429	13529892	39,38	66964286	29088136	56,56	Fail
128	100	50675676	12668919	3792798	70,06	38006757	20880846	45,06	Fail
256	100	27173914	6793479	1918984	71,75	20380435	11475425	43,69	Fail
512	100	14097746	3524437	3313398	5,99	10573309	3683671	65,16	Fail
1024	100	7183908	1795977	1346084	25,05	5387931	2232593	58,56	Fail
1280	100	5769232	1442308	1362413	5,54	4326924	1513763	65,02	Fail
1518	100	4876464	1219116	551574	54,76	3657348	1880644	48,58	Fail

C-Port: Congested Port

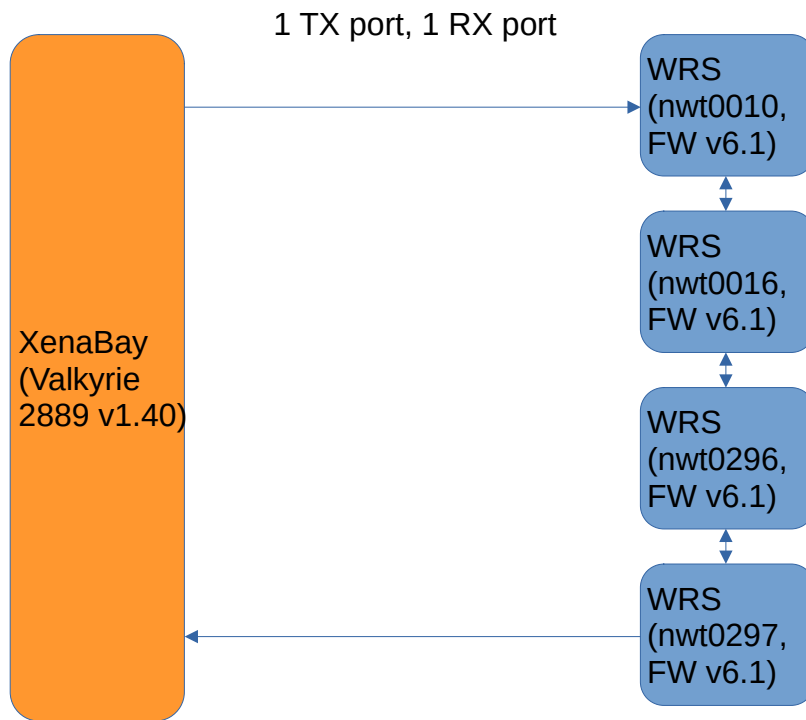
UC-Port: Uncongested Port

2.5. Forward Pressure Results, 4 layers



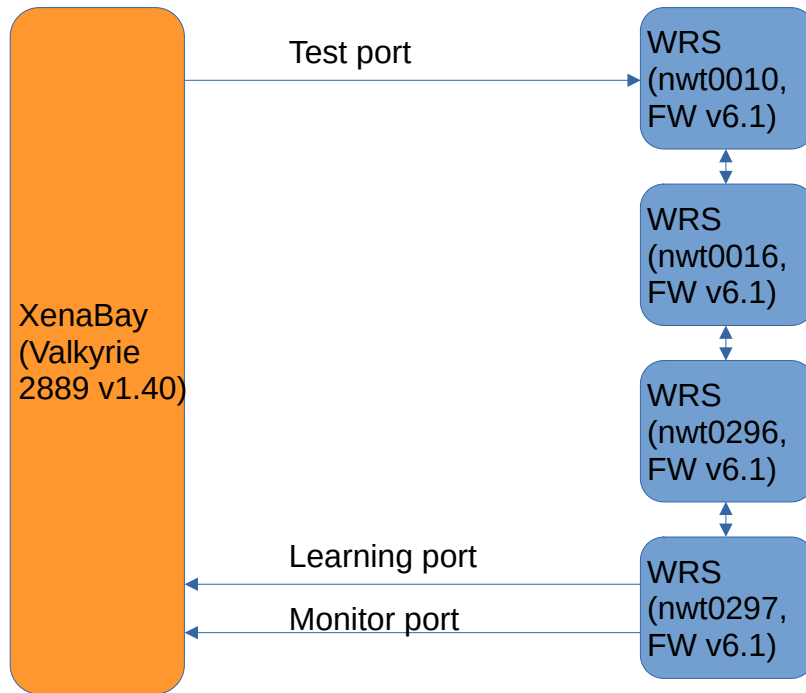
Frame Size, bytes	Tx Frames	Tx max. util., %	Rx Frames	Rx max. util., %	Loss, %	Result
64	45180722	101,205	42613551	95,45	5,68	Pass
128	25510204	100,68	24671032	97,368	3,29	Pass
256	13636363	100,364	13392872	98,571	1,79	Pass
512	7062146	100,188	6996305	99,253	0,93	Pass
1024	3595397	100,096	3578293	99,618	0,48	Pass
1280	2886048	100,05	2875032	99,693	0,38	Pass
1518	2439817	100,065	2431956	99,74	0,32	Pass

2.6. Maximum Forwarding Rate Results, 4 layers



Frame Size, bytes	Tx Rate, %	Tx Rate, f/s	Tx Frames	Rx Frames	Loss, % (calculated)	Result
64	90,04	1339,9K	40196901	40050411	0,4	Pass
128	100	844,5K	25337837	24671036	2,6	Pass
256	100	452,9K	13586956	13392868	1,4	Pass
512	100	234,9K	7048872	6996303	0,7	Pass
1024	100	119,7K	3591954	3578293	0,4	Pass
1280	100	96,1K	2884615	2875818	0,3	Pass
1518	80	65K	1950585	1950585	0	Pass

2.7. Address Caching Capacity and Learning Rate Results, 4 layers



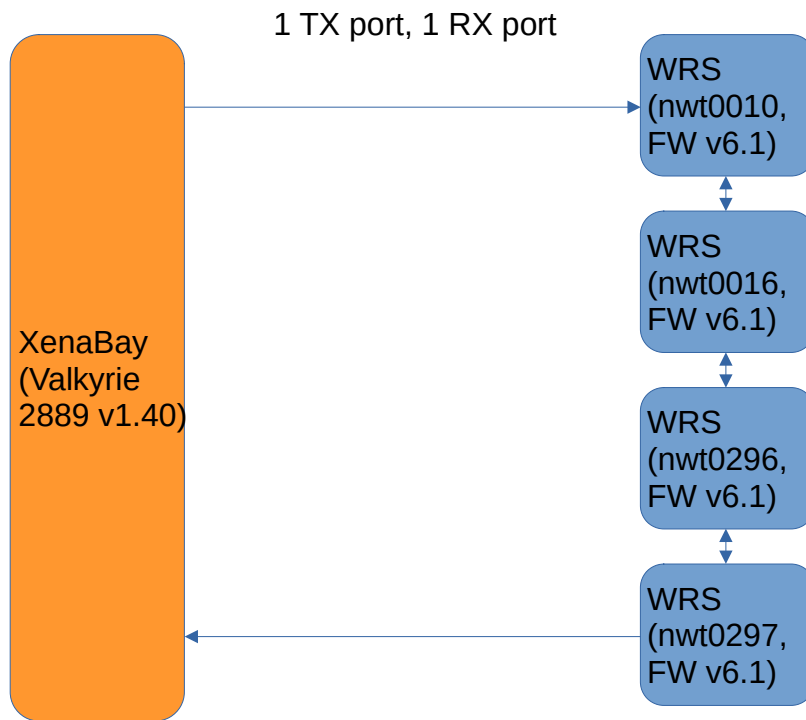
Address Caching Capacity (Learning Rate=20 frames/s)

Frame Size, bytes	Address Count	Test Port Tx Frames	Learn Port Rx Frames	Monitor Port Rx Frames	Result
64	1074	1074	1073	0	Fail
128	404	404	404	0	Pass
256	160	160	160	0	Pass
512	160	160	160	0	Pass
1024	160	160	160	0	Pass
1280	160	160	160	0	Pass
1518	160	160	160	0	Pass

Address Learning Rate, frame/s (Base Learning Rate=100 frames/s)

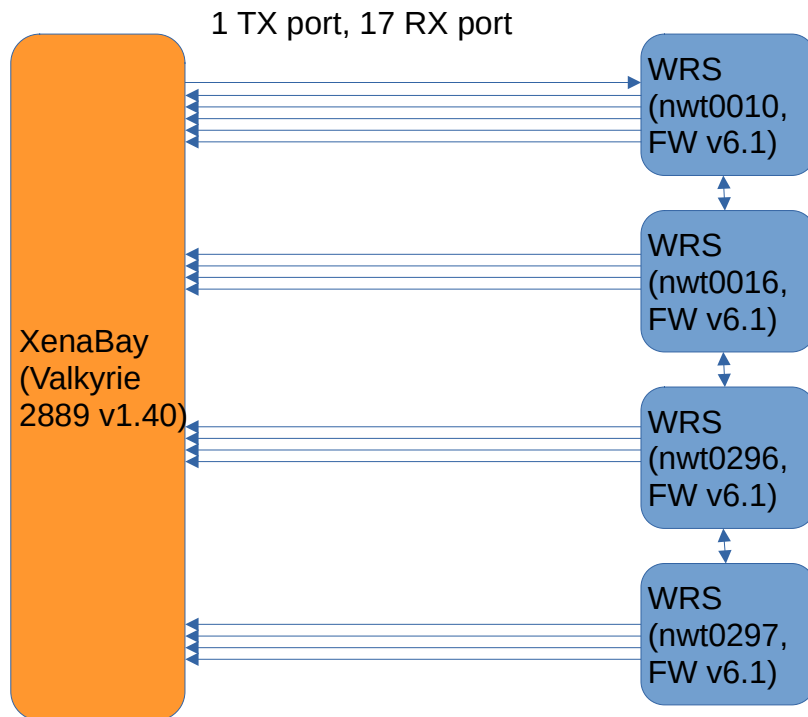
Frame size, byte Address count	64	128	256	512	1024	1280	1518
100	80	80	80	80	80	40	80
612	20						
1124	20						
1636	20						
2048	20						
404		20					
160			80	80	80	80	80

2.8. Errored Frames Filtering Results, 4 layers

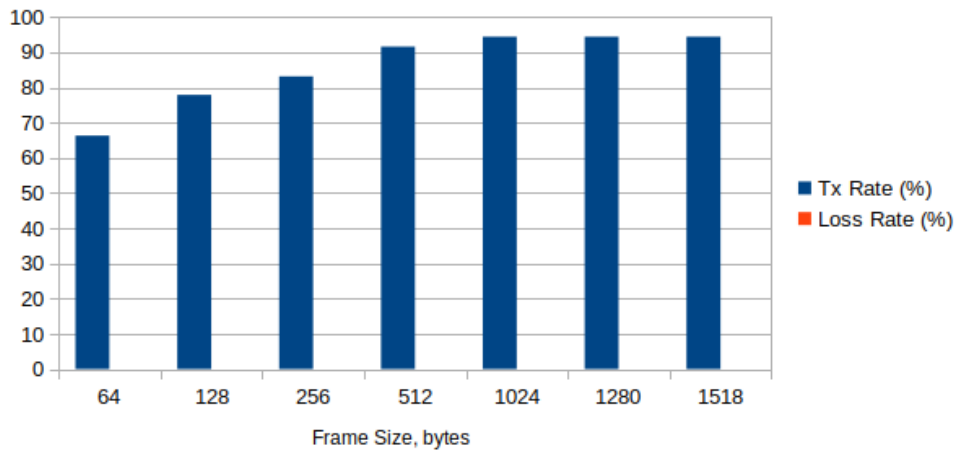


Tx Rate, %	Tx Frames	Rx Frames	Tx Valid	Rx Valid	Tx Over size	Rx Over size	Tx Under size	Rx Under size	Tx FCS Error	Rx FCS Error	Result
10	1741343	1740465	154130	154130	81214	81214	1505999	1505121	58	0	Fail
20	3482752	3480930	308261	308261	162443	162443	3012048	3010226	58	0	Fail
30	5224128	5221495	462392	462392	243664	243664	4518072	4515439	58	0	Fail
40	6965419	6961801	616522	616522	324801	324801	6024096	6020478	58	0	Fail
50	8706880	8702374	770653	770653	406107	406107	7530120	7525614	58	0	Fail
60	10448257	10442887	924784	924784	487329	487329	9036144	9030774	58	0	Fail
70	12189633	12183437	1078914	1078914	568551	568551	10542168	10535972	58	0	Fail
80	13931009	13923924	1233045	1233045	649772	649772	12048192	12041107	58	0	Fail
90	15672386	15663306	1387176	1387176	730994	730994	13554216	13545136	58	0	Fail
100	17413762	13732361	1541307	1477951	812215	632652	15060240	11621758	58	0	Fail

2.9. Broadcast Forwarding Results, 4 layers

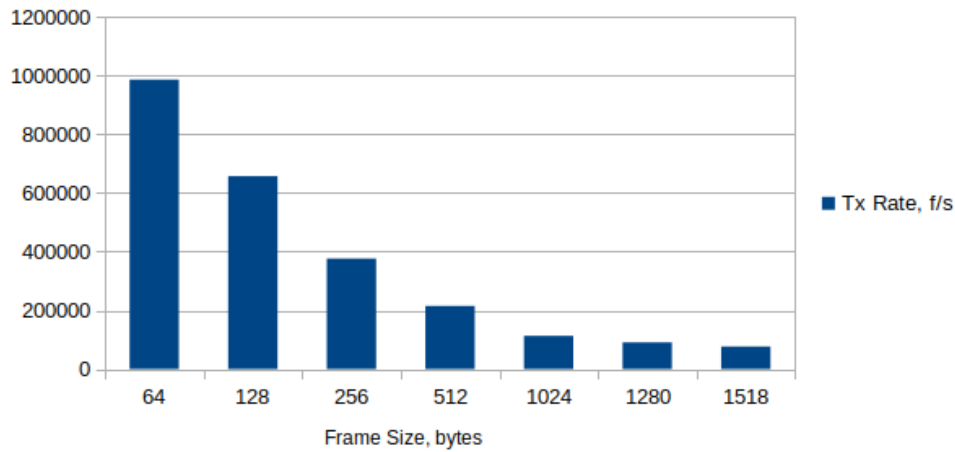


Broadcast Forwarding Rate, % (4 layers)



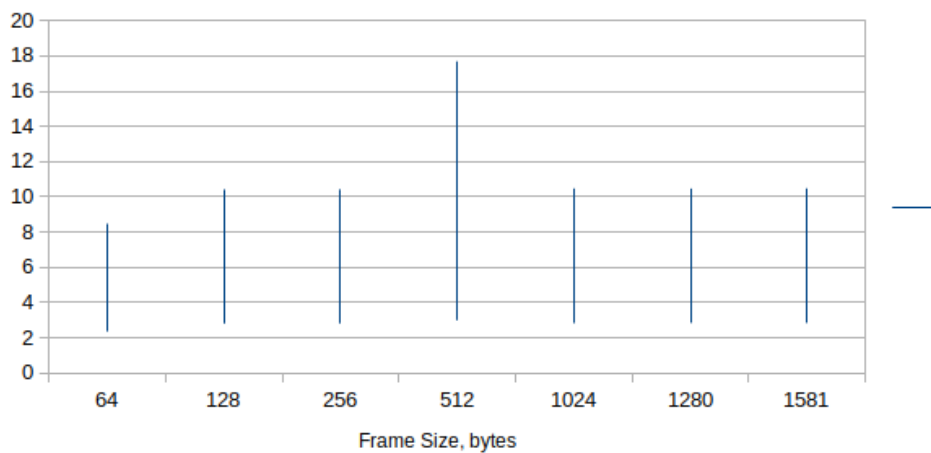
Frame Size, bytes	Tx Rate, %	Loss Rate, %	Loss Frames	Result
64	66,29	0	0	Pass
128	77,85	0	0	Pass
256	83,12	0	0	Pass
512	91,56	0	0	Pass
1024	94,37	0	0	Pass
1280	94,37	0	0	Pass
1518	94,37	0	0	Pass

Broadcast Throughput, frame/s (4 layers)



Frame Size, bytes	Tx Rate (Fps)
64	986346
128	657414
256	376442
512	215107
1024	112997
1280	90745
1518	76688

Broadcast Forwarding Average Latency, usec (4 layers)



All layers

Frame Size, bytes	Latency, usec			Jitter, usec		
	Average	Min	Max	Average	Min	Max
64	2,3-8,5	2,24-8,26	5,92-13,33	0,003-0,04	0	2,45-2,77
128	2,8-10,4	2,70-10,17	6,14-13,87	0,002-0,03	0	2,17-2,33
256	2,8-10,4	2,69-10,16	4,86-12,52	0,005-0,01	0	2,00-2,21
512	2,9-17,7	2,70-10,16	8,24-36,70	0,002-0,01	0	2,10-2,31
1024	2,8-10,5	2,72-10,21	4,90-12,67	0,002-0,003	0	2,10-2,33
1280	2,8-10,5	2,70-10,20	4,72-12,50	0,002-0,003	0	1,88-2,10
1518	2,8-10,5	2,71-10,22	4,68-12,34	0,001-0,002	0	1,85-2,07

1st Layer

Frame Size, bytes	Latency, usec			Jitter, usec		
	Average	Min	Max	Average	Min	Max
64	2,35-2,39	2,24-2,29	5,92-6,18	0,003-0,04	0	2,4-2,77
128	2,80-2,86	2,70-2,73	6,14-7,22	0,002-0,03	0	2,11-2,33
256	2,80-2,82	2,70-2,72	4,86-5,00	0,005-0,01	0	2,02-2,12
512	2,98-17,69	2,70-2,73	8,24-36,69	0,002-0,01	0	2,07-2,37
1024	2,82-2,86	2,72-2,72	4,88-5,15	0,002-0,003	0	2,10-2,33
1280	2,83-2,86	2,70-2,73	4,72-4,96	0,002-0,003	0	1,88-2,10
1518	2,84-2,85	2,71-2,73	4,68-4,92	0,001-0,002	0	1,85-2,07

2nd Layer

Frame Size, bytes	Latency, usec			Jitter, usec		
	Average	Min	Max	Average	Min	Max
64	3,96-3,98	3,79-3,83	8,72-9,37	0,003-0,02	0	2,6-2,64
128	4,91-4,93	4,71-4,76	8,29-9,01	0,010-0,01	0	2,12-2,14
256	4,86-4,88	4,70-4,75	6,89-6,96	0,005-0,01	0	1,99-2,12
512	5,08-5,11	4,71-4,76	11,71-11,78	0,002-0,007	0	2,09-2,31
1024	4,89-4,92	4,72-4,77	6,96-7,11	0,002-0,003	0	2,09
1280	4,88-4,91	4,73-4,78	6,87-6,99	0,002-0,003	0	2,44
1518	4,89-4,93	4,74-4,79	6,76-6,88	0,002	0	1,88-1,9

3rd Layer

Frame Size, bytes	Latency, usec			Jitter, usec		
	Average	Min	Max	Average	Min	Max
64	6,20-6,25	6,00-6,04	10,98	0,016-0,022	0	2,61
128	7,57-7,65	7,39-7,50	10,99-11,06	0,002-0,01	0	2,14
256	7,54-7,64	7,37-7,49	9,65-9,75	0,01	0	2,09-2,17
512	7,78-7,88	7,39-7,50	14,42-14,52	0,005-0,007	0	2,21
1024	7,59-7,70	7,42-7,51	9,73-9,85	0,002-0,003	0	2,12
1280	7,58-7,69	7,40-7,52	9,61-9,73	0,003	0	2,44
1518	7,59-7,70	7,41-7,53	9,45-9,55	0,002	0	1,9

4th Layer

Frame Size, bytes	Latency, usec			Jitter, usec		
	Average	Min	Max	Average	Min	Max
64	8,43-8,46	8,19-8,26	13,26-13,33	0,016-0,022	0	2,61-2,64
128	10,37-10,41	10,10-10,17	13,80-13,87	0,002-0,01	0	2,14-2,24
256	10,39-10,42	10,06-10,16	12,44-12,52	0,01	0	2,04-2,12
512	10,63-10,66	10,07-10,17	17,26-17,31	0,005-0,007	0	2,12-2,21
1024	10,44-10,47	10,14-10,21	12,59-12,66	0,002-0,003	0	2,12
1280	10,43-10,47	10,10-10,19	12,45-12,50	0,003	0	2,04
1518	10,44-10,47	10,15-10,22	12,29-12,34	0,002	0	1,9