APPENDIX B

Test Result Analysis

This appendix provides some comparison and analysis of the test results in Appendix C, "Complete Test Data." The analysis summarizes and compare test cases from a variety of test suites to draw conclusions. These conclusions and the overall test approach are described in Chapter 7, "Testing the CPwE Solution." The key analysis includes the following:

- Impact of the number of switches on network convergence in a ring topology (8 versus 16 switches)
- Impact of Spanning Tree Protocol (STP) on network convergence in a ring topology.
- Impact of topology/resiliency protocol on network convergence (ring vs. redundant star topologies) with both copper and fiber media situations
- Impact of uplink media type used (fiber versus copper) on network convergence
- Impact of number of MAC addresses on network convergence
- Analysis of network restoration events
- Analysis of application latency (screw-to-screw) tests

The summary of the test case includes the following:

- Minimum, maximum, and average measured network convergence from the all test iterations and measurement points as a set
- The maximum measured network convergence in east test iteration averaged for all test iterations (MaxAvg)

All of this information is valuable. As the purpose of this section is to compare the test results and draw conclusions, it is useful to compare some information between the test cases. Cisco and Rockwell Automation chose to use the MaxAvg as the best representation of network convergence between the test suites on which to draw conclusions. The minimum and maximum numbers, although informative, were not useful as a basis to analyze and draw conclusions. The average of the set of test iterations was also not used as this number varies significantly when some measurement points are more impacted than others depending on the test suite. The MaxAvg, therefore, was determined to be a better representation of network convergence when analyzing and drawing conclusions.

Impact of the Number of Switches (RMC8 vs. RMC16)

This section compares the network convergence for the 8- and 16-switch ring topologies with copper uplinks and MSTP as the resiliency protocol based on peer-to-peer (UDP unicast) traffic streams. This section provides tables that compare the following:

- Minimum measured convergence of the set of test cases
- Maximum measured convergence of the set of test cases
- Average of the measure convergence time
- Average of the highest measured convergence from each test iteration (MaxAvg)

Note The values in the following tables are in seconds.

Table B-1 Test Case 1- Bring link 7 to 8 down (software) - RMC8 vs RMC16

Ucast	Baseline		200 MAC		400 MAC	
	RMC8	RMC16	RMC8	RMC16	RMC8	RMC16
Min	0.380	0.387	0.397	0.401	0.394	0.403
Max	1.793	2.422	2.362	2.755	2.382	2.717
Avg	0.768	1.219	0.885	1.134	0.774	1.162
MaxAvg	0.977	1.794	1.104	1.656	0.990	1.670

Table B-2 Test Case 2 - Bring link 7 to 8 up (software) - RMC8 vs RMC16

Ucast	Baseline		200 MAC		400 MAC	
	RMC8	RMC16	RMC8	RMC16	RMC8	RMC16
Min	0.007	0.005	0.013	0.016	0.022	0.023
Max	0.123	0.035	0.190	0.046	0.197	0.063
Avg	0.029	0.013	0.058	0.027	0.067	0.039
MaxAvg	0.052	0.022	0.098	0.038	0.109	0.053

Table B-3 Test Case 3 - Disconnect cable from 7 to 8 (physical) - RMC8 vs RMC16

Ucast	Baseline		200 MAC		400 MAC	
	RMC8	RMC16	RMC8	RMC16	RMC8	RMC16
Min	0.380	0.382	0.386	0.384	0.393	0.394
Max	1.863	1.871	1.746	1.377	2.348	2.369
Avg	0.829	1.047	0.653	0.812	0.892	0.952
MaxAvg	1.118	1.416	0.745	1.064	1.157	1.413

Table B-4 Test Case 4 - Reconnect Cable from 7 to 8 - RMC8 vs RMC16

Ucast	Baseline		200 MAC		400 MAC	
	RMC8	RMC16	RMC8	RMC16	RMC8	RMC16
Min	0.008	0.006	0.016	0.016	0.021	0.023
Max	0.088	0.038	0.173	0.046	0.209	0.065

Table B-4 Test Case 4 - Reconnect Cable from 7 to 8 - RMC8 vs RMC16 (continued)

Ucast	Baseline		200 MAC		400 MAC	
	RMC8	RMC16	RMC8	RMC16	RMC8	RMC16
Avg	0.027	0.016	0.048	0.024	0.066	0.041
MaxAvg	0.050	0.029	0.085	0.035	0.110	0.057

Table B-5 Test Case 5 - Root bridge down (physical) - RMC8 vs RMC16

Ucast	Baseline		200 MAC		400 MAC	
	RMC8	RMC16	RMC8	RMC16	RMC8	RMC16
Min	0.000	0.000	0.011	0.000	0.000	0.000
Max	1.852	1.637	1.765	1.650	2.565	1.296
Avg	0.438	0.547	0.501	0.460	0.570	0.415
MaxAvg	0.759	0.978	0.752	0.871	0.959	0.655

Table B-6 Test Case 6 - Root bridge up (physical) - RMC8 vs RMC16

Ucast	Baseline		200 MAC		400 MAC	
	RMC8	RMC16	RMC8	RMC16	RMC8	RMC16
Min	0.017	0.008	0.034	0.022	0.045	0.048
Max	1.070	0.922	0.905	0.942	1.079	0.928
Avg	0.283	0.286	0.271	0.239	0.327	0.320
MaxAvg	0.489	0.499	0.388	0.444	0.463	0.465

Table B-7 Test Case 7 - Stack Master down - RMC8 vs RMC16

Ucast	Baseline		200 MAC		400 MAC	
	RMC8	RMC16	RMC8	RMC16	RMC8	RMC16
Min	0.000	0.000	0.000	0.000	0.000	0.000
Max	1.737	1.762	2.748	1.864	2.401	1.815
Avg	0.435	0.501	0.498	0.538	0.493	0.545
MaxAvg	0.809	0.936	0.895	1.036	0.857	0.991

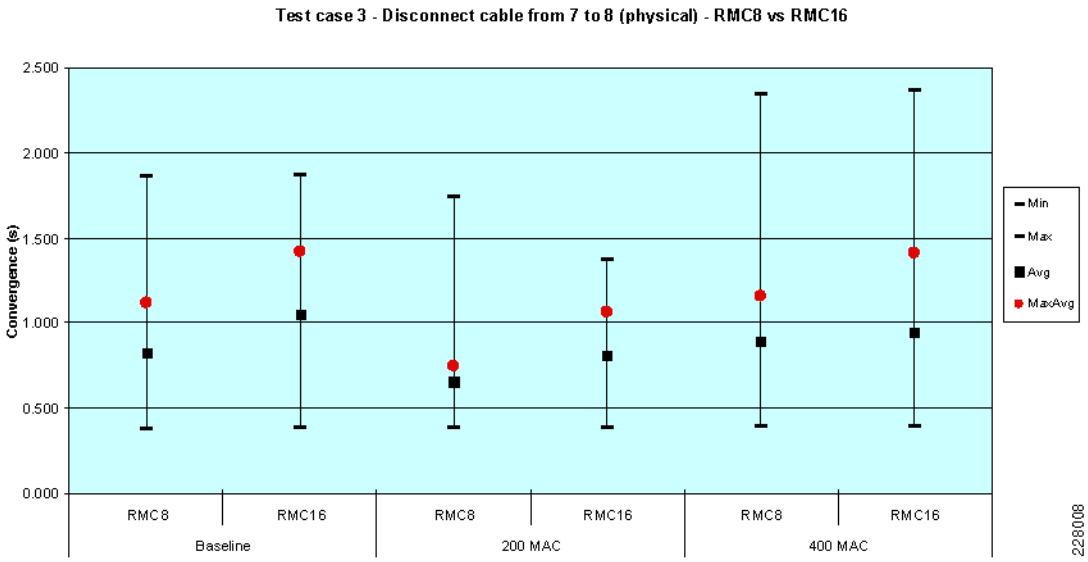
Table B-8 Test Case 8 - Stack Master up - RMC8 vs RMC16

Ucast	Baseline		200 MAC		400 MAC	
	RMC8	RMC16	RMC8	RMC16	RMC8	RMC16
Min	0.000	0.000	0.000	0.000	0.000	0.000
Max	0.137	0.036	0.184	0.049	0.194	0.072
Avg	0.029	0.012	0.052	0.022	0.054	0.028
MaxAvg	0.055	0.020	0.079	0.031	0.086	0.041

Figure B-1 shows the trend for physical cable disconnection (test case 3) between 8- and 16-switch ring topologies. In all cases, the number of switches slowed the network convergence of the STP. The same trend can be seen in the following failure test cases:

- Test Case 1—Bring Link Down
- Test Cast 3—Disconnect Cable
- Test Case 5—Root Bridge Down
- Test Case 7—Stack Master Down

Figure B-1 Impact of Number of Switches—Test Case 3 Disconnect Cable



The key findings were as follows:

- Convergence time on average is below one second, which is sufficient to avoid application timeouts for process and HMI applications (non-time critical). None of the test suites meet the requirements to avoid application timeouts in time-critical applications.
- The size of the ring impacts (slows down) the network convergence in link disruption test cases, although with the variability due to the copper media, this impact is difficult to quantify. The number of network infrastructure devices has less relevance in the other test cases.
- The impact of the number of MAC addresses was difficult to assess, most likely due to the variance introduced by the copper uplinks

Spanning Tree Protocol Comparison (RMC8 vs. RPC8)

This section compares the MSTP and rapid PVST+ (RPVST+) STPs in 8-switch ring topologies with copper uplinks. This section provides tables that compare the following:

- Minimum measured convergence of the set of test cases
- Maximum measured convergence of the set of test cases
- Average of the measure convergence time
- Average of the highest measured convergence from each test iteration (MaxAvg)

Table B-9 Test Case 1 - Bring link 7 to 8 down (software) - RMC8 vs RPC8

Ucast	Baseline	
	RMC8	RPC8
Min	0.380	0.395
Max	1.793	0.868
Avg	0.768	0.597
MaxAvg	0.977	0.610

Table B-10 Test Case 2 - Bring link 7 to 8 up (software) - RMC8 vs RPC8

Ucast	Baseline	
	RMC8	RPC8
Min	0.007	0.007
Max	0.123	0.043
Avg	0.029	0.020
MaxAvg	0.052	0.028

Table B-11 Test Case 3 - Disconnect cable from 7 to 8 (physical) - RMC8 vs RPC8

Ucast	Baseline	
	RMC8	RPC8
	RMC8	RPC8
Min	0.380	0.390
Max	1.863	0.863
Avg	0.829	0.651
MaxAvg	1.118	0.675

Table B-12 Test Case 4 - Reconnect cable from 7 to 8 - RMC8 vs RPC8

Ucast	Baseline	
	RMC8	RPC8
Min	0.008	0.009
Max	0.088	0.042
Avg	0.027	0.021
MaxAvg	0.050	0.030

Table B-13 Test Case 5 - Root bridge down (physical) - RMC8 vs RPC8

Ucast	Baseline	
	RMC8	RPC8
Min	0.000	0.000
Max	1.852	0.894
Avg	0.438	0.294
MaxAvg	0.759	0.577

Table B-14 Test Case 6 - Root bridge up (physical) - RMC8 vs RPC8

Ucast	Baseline	
	RMC8	RPC8
Min	0.017	0.013
Max	1.070	0.328
Avg	0.283	0.039
MaxAvg	0.489	0.055

Table B-15 Test Case 7 - Stack Master down - RMC8 vs RPC8

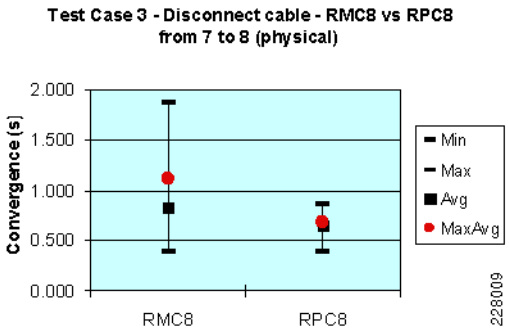
Ucast	Baseline	
	RMC8	RPC8
Min	0.000	0.000
Max	1.737	0.875
Avg	0.435	0.311
MaxAvg	0.809	0.612

Table B-16 Test Case 8 - Adding switch back to the stack - RMC8 vs RPC8

Ucast	Baseline	
	RMC8	RPC8
Min	0.000	0.000
Max	0.137	0.046
Avg	0.029	0.014
MaxAvg	0.055	0.024

Figure B-2 shows the trend for physical cable disconnection (test case 3) for each compared test suite.

Figure B-2 Disconnect cable



The key findings are as follows:

- In all key disruptions, including link disruption, stack-master and root-switch failure test cases, the peer-to-peer application timed out in all instances. Neither protocol converges the network in this configuration near the requirements to avoid timeouts in "time critical" applications
- RPVST+ network convergence is generally faster and less variable than MSTP.

In general, network convergence was fast enough in reestablishing links and restoring a switch in the switch-stack test cases to avoid peer-to-peer application timeouts. This suggests restoring connectivity may not require planned downtime for peer-to-peer applications. I/O (multicast-based) applications were not tested. See the "Restore Impact Analysis" section on page B-25 for more information.

Topology/Resiliency Protocol Analysis

This section compares the test results from the various topology and resiliency protocol test suites. The analysis is split into two sections to compare the copper and fiber media-uplink test suites. This section provides tables that compare the following:

- Minimum measured convergence of the set of test cases
- Maximum measured convergence of the set of test cases
- Average of the measure convergence time
- Average of the highest measured convergence from each test iteration (MaxAvg)

Topology/Resiliency Protocol Analysis—Copper Uplinks (RMC8, SMC8, SEC8, SFC8)

This section compares the topologies and resiliency protocols (MSTP, EtherChannel, and Flex Links) in 8-switch topologies with copper uplinks based on peer-to-peer (UDP unicast) traffic streams.

Table B-17 Test Case 1- Bring link down (software) - RMC8, SMC8, SEC8 & SFC8

Ucast	Baseline				200 MAC				400 MAC			
	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8
Min	0.380	0.001	0.0047	0.010	0.397	0.001	0.005	0.022	0.394	0.0007	0.0066	0.034
Max	1.793	0.815	0.0726	0.058	2.362	0.425	0.179	0.146	2.382	0.4165	0.1396	0.172
Avg	0.768	0.317	0.0279	0.022	0.885	0.173	0.038	0.069	0.774	0.1311	0.0381	0.086
MaxAvg	0.977	0.632	0.0373	0.032	1.104	0.345	0.055	0.106	0.990	0.2612	0.0585	0.128

Table B-18 Test Case 2- Bring link up (software) - RMC8, SMC8, SEC8, SFC8

Ucast	Baseline				200 MAC				400 MAC			
	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8
Min	0.007	0.000	0	0.010	0.013	0.000	0	0.019	0.022	0.000	0	0.020
Max	0.123	0.032	0	0.037	0.190	0.016	0	0.104	0.197	0.017	0	0.158
Avg	0.029	0.015	0	0.020	0.058	0.009	0	0.046	0.067	0.010	0	0.068
MaxAvg	0.052	0.019	0	0.030	0.098	0.012	0	0.072	0.109	0.013	0	0.111

Table B-19 Test Case 3 - Disconnect cable (physical) - RMC8, SMC8, SEC8, SFC8

Ucast	Baseline				200 MAC				400 MAC			
	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8
Min	0.380	0.370	0.3498	0.387	0.386	0.180	0.3565	0.401	0.393	0.180	0.3488	0.415
Max	1.863	0.795	0.7696	0.811	1.746	0.787	0.7622	0.853	2.348	0.791	0.7671	0.856
Avg	0.829	0.581	0.5627	0.673	0.653	0.368	0.5648	0.628	0.892	0.389	0.563	0.696
MaxAvg	1.118	0.778	0.5671	0.677	0.745	0.508	0.5707	0.646	1.157	0.585	0.5709	0.720

Table B-20 Test Case 5 - Stack Master down (software) - RMC8, SMC8, SEC8, SFC8

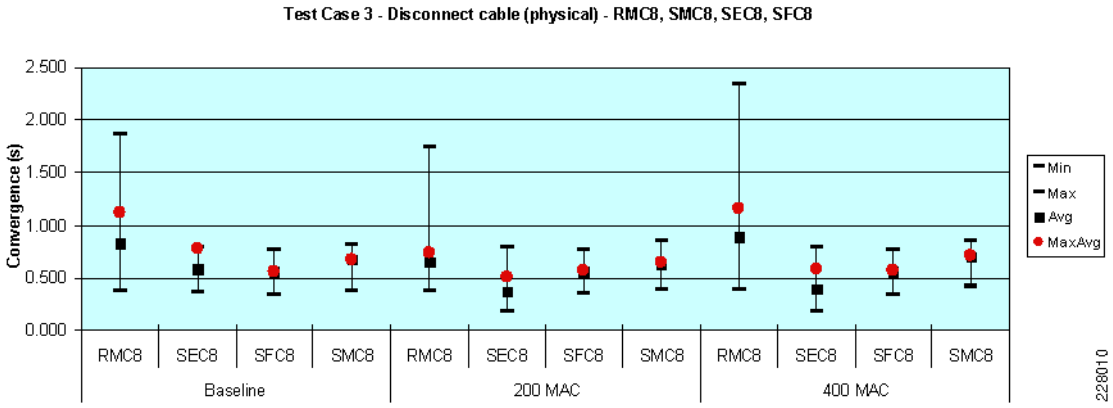
Ucast	Baseline				200 MAC				400 MAC			
	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8
Min	0.000	0.000	0.3617	0.406	0.000	0.578	0.3695	0.425	0.000	0.598	0.4165	0.499
Max	1.737	1.227	0.8011	0.854	2.748	1.125	0.8065	0.938	2.401	1.004	1.243	0.954
Avg	0.435	0.602	0.6114	0.679	0.498	0.781	0.6341	0.683	0.493	0.681	0.8107	0.758
MaxAvg	0.809	0.847	0.6183	0.786	0.895	0.814	0.6469	0.796	0.857	0.687	0.8367	0.865

Table B-21 Test Case 6 - Restore stack switch (software) - RMC8, SMC8, SEC8, SFC8

Ucast	Baseline				200 MAC				400 MAC			
	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8	RMC8	SEC8	SFC8	SMC8
Min	0.000	0.000	0	0.023	0.000	0.006	0	0.052	0.000	0.007	0	0.072
Max	0.137	1.094	0.0008	0.840	0.184	0.396	0.0006	0.163	0.194	0.343	0.001	0.292
Avg	0.029	0.126	0.0002	0.104	0.052	0.062	8E-05	0.082	0.054	0.045	0.0001	0.127
MaxAvg	0.055	0.131	0.0002	0.132	0.079	0.069	8E-05	0.117	0.086	0.062	0.0001	0.175

Figure B-3 shows the trend for physical cable-disconnection for the test suites compared.

Figure B-3 Disconnect Cable (Test Case 3)



Note SMC8 test results include measurements between switches IES-4 and -5. This switch was not impacted by the link failure. This explains the low test results for this test suite.

The key findings are as follows:

- In all key disruptions, including cable-disconnect and stack-master failure test cases, the time-critical application timed out in all instances. No combination of topology and resiliency protocol with copper uplinks could converge the network within the requirements to avoid timeouts in time-critical applications.
- For key all key disruptions, the ring topology converged more slowly than redundant star topologies, independent of resiliency protocols.
- The Flex Links and EtherChannel configurations generally outperformed the Spanning Tree configuration.
- The impact of the number of MAC addresses was difficult to assess, most likely due to the variance introduced by the copper uplinks
- In general, network convergence was fast enough in the reestablishing links and restoring a switch in the switch-stack test cases to avoid peer-to-peer application timeouts. This suggests restoring connectivity may not require planned downtime. I/O (multicast-based) applications were not tested.

Topology/Resiliency Protocol Analysis—Fiber Uplinks (RMF8, SMF8, SEF8, SFF8)

This section compares the network convergence between topologies and resiliency protocols (MSTP, EtherChannel, and Flex Links) in 8-switch topologies with fiber uplinks based on peer-to-peer (UDP unicast) traffic streams followed by IO (UDP multicast) traffic streams.

Table B-22 Test Case 1 - Bring link down (software) - RMF8, SMF8, SEF8 & SFF8

Ucast	Baseline				200 MAC				400 MAC			
	RMF8	SEF8	SFF8	SMF8	RMF8	SEF8	SFF8	SMF8	RMF8	SEF8	SFF8	SMF8
Min	0.051	0.000	0.005	0.011	0.051	0.000	0.012	0.031	0.063	0.000	0.005	0.046
Max	1.497	0.097	0.068	0.064	1.939	0.051	0.057	0.104	1.622	0.049	0.065	0.174
Avg	0.269	0.040	0.030	0.028	0.286	0.020	0.030	0.055	0.196	0.019	0.030	0.078
MaxAvg	0.467	0.075	0.040	0.043	0.464	0.039	0.037	0.077	0.318	0.038	0.043	0.103

Table B-23 Test Case 2 - Bring link up (software) - RMF8, SMF8, SEF8 & SFF8

Ucast	Baseline				200 MAC				400 MAC			
	RMF8	SEF8	SFF8	SMF8	RMF8	SEF8	SFF8	SMF8	RMF8	SEF8	SFF8	SMF8
Min	0.007	0.000	0.000	0.010	0.007	0.000	0.000	0.019	0.021	0.000	0.000	0.030
Max	0.039	0.025	0.000	0.040	0.053	0.012	0.000	0.082	0.083	0.015	0.000	0.136
Avg	0.016	0.010	0.000	0.020	0.023	0.005	0.000	0.041	0.042	0.006	0.000	0.075
MaxAvg	0.028	0.012	0.000	0.029	0.043	0.006	0.000	0.062	0.061	0.007	0.000	0.119

Table B-24 Test Case 3 - Disconnect cable (physical) - RMF8, SMF8, SEF8 & SFF8

Ucast	Baseline				200 MAC				400 MAC			
	RMF8	SEF8	SFF8	SMF8	RMF8	SEF8	SFF8	SMF8	RMF8	SEF8	SFF8	SMF8
Min	0.007	0.000	0.023	0.024	0.007	0.000	0.005	0.072	0.048	0.000	0.027	0.080
Max	1.987	0.132	0.075	0.157	1.417	0.063	0.058	0.144	1.173	0.062	0.097	0.175
Avg	0.309	0.051	0.052	0.078	0.234	0.026	0.039	0.098	0.322	0.026	0.049	0.118
MaxAvg	0.575	0.080	0.061	0.091	0.545	0.044	0.048	0.111	0.575	0.044	0.057	0.136

Table B-25 Test Case 4 - Reconnect cable (physical) - RMF8, SMF8, SEF8 & SFF8

Ucast	Baseline				200 MAC				400 MAC			
	RMF8	SEF8	SFF8	SMF8	RMF8	SEF8	SFF8	SMF8	RMF8	SEF8	SFF8	SMF8
Min	0.007	0.000	0.000	0.010	0.007	0.000	0.000	0.020	0.022	0.000	0.000	0.030
Max	0.040	0.023	0.000	0.045	0.049	0.013	0.000	0.088	0.073	0.014	0.000	0.149
Avg	0.017	0.009	0.000	0.019	0.023	0.005	0.000	0.043	0.039	0.006	0.000	0.080
MaxAvg	0.030	0.011	0.000	0.028	0.043	0.006	0.000	0.064	0.057	0.007	0.000	0.129

Table B-26 Test Case 5 - Stack Master down (software) - SMF8, SEF8 & SFF8

Ucast	Baseline			200 MAC			400 MAC		
	SEF8	SFF8	SMF8	SEF8	SFF8	SMF8	SEF8	SFF8	SMF8
Min	0.000	0.027	0.070	0.569	0.025	0.121	0.588	0.050	0.173
Max	1.232	0.086	0.127	0.668	0.073	0.202	0.667	0.103	0.269
Avg	0.545	0.053	0.096	0.612	0.054	0.158	0.617	0.075	0.215
MaxAvg	0.846	0.059	0.109	0.624	0.063	0.180	0.624	0.083	0.236

Table B-27 Test Case SMF8, SEF8, SFF8-6 - Stack Maser up (software)

Ucast	Baseline			200 MAC			400 MAC		
	SEF8	SFF8	SMF8	SEF8	SFF8	SMF8	SEF8	SFF8	SMF8
Min	0.000	0.000	0.021	0.006	0.000	0.025	0.007	0.000	0.074
Max	0.043	0.000	0.085	0.565	0.000	0.176	0.506	0.000	0.180
Avg	0.017	0.000	0.045	0.052	0.000	0.076	0.051	0.000	0.113
MaxAvg	0.021	0.000	0.058	0.083	0.000	0.101	0.077	0.000	0.138

Table B-28 Test Case 1 - Bring link down (software) - RMF8, SMF8, SEF8 & SFF8

Mcast	Baseline		200 MAC		400 MAC	
	SEF8	SFF8	SEF8	SFF8	SEF8	SFF8
Min	0.000	0.005	0.001	0.012	0.001	0.005
Max	0.097	0.045	0.098	0.041	0.096	0.033
Avg	0.040	0.019	0.039	0.023	0.038	0.016
MaxAvg	0.075	0.019	0.076	0.023	0.075	0.016

Table B-29 Test Case 2 - Bring link up (software) - RMF8, SMF8, SEF8 & SFF8

Mcast	Baseline		200 MAC		400 MAC	
	SEF8	SFF8	SEF8	SFF8	SEF8	SFF8
Min	0.000	0.000	0.005	0.000	0.005	0.000
Max	0.025	0.000	0.027	0.000	0.035	0.000
Avg	0.012	0.000	0.016	0.000	0.019	0.000
MaxAvg	0.014	0.000	0.018	0.000	0.023	0.000

Table B-30 Test Case 3 - Disconnect cable (physical) - RMF8, SMF8, SEF8 & SFF8

Mcast	Baseline		200 MAC		400 MAC	
	SEF8	SFF8	SEF8	SFF8	SEF8	SFF8
Min	0.000	0.014	0.009	0.008	0.014	0.000
Max	0.132	0.077	0.126	0.058	0.125	0.097
Avg	0.050	0.043	0.059	0.031	0.058	0.037
MaxAvg	0.080	0.060	0.087	0.046	0.087	0.053

Table B-31 Test Case 4 - Reconnect cable (physical) - RMF8, SMF8, SEF8 & SFF8

Mcast	Baseline		200 MAC		400 MAC	
	SEF8	SFF8	SEF8	SFF8	SEF8	SFF8
Min	0.000	0.000	0.005	0.000	0.005	0.000
Max	0.023	0.000	0.028	0.000	0.034	0.008
Avg	0.013	0.000	0.016	0.000	0.019	0.001
MaxAvg	0.015	0.000	0.018	0.000	0.022	0.001

Table B-32 Test Case 5 - Stack Master down (software) - SMF8, SEF8 & SFF8

Mcast	Baseline		200 MAC		400 MAC	
	SEF8	SFF8	SEF8	SFF8	SEF8	SFF8
Min	0.000	0.023	0.000	0.020	0.000	0.019
Max	1.232	0.055	1.240	0.061	2.115	0.040
Avg	0.545	0.035	0.551	0.037	0.642	0.028
MaxAvg	0.846	0.035	0.848	0.037	0.943	0.028

Table B-33 Test Case SMF8, SEF8, SFF8-6 - Stack Maser up (software)

Mcast	Baseline		200 MAC		400 MAC	
	SEF8	SFF8	SEF8	SFF8	SEF8	SFF8
Min	0.000	0.000	0.000	0.000	0.000	0.000
Max	39.579	0.000	41.247	0.000	66.788	8.619
Avg	7.879	0.000	6.103	0.000	9.465	1.019
MaxAvg	15.744	0.000	11.844	0.000	18.302	1.019

Table B-34 shows the maximum measured convergence per test-iteration average (MaxAvg) for both unicast and multicast test streams and the frequency of application timeouts for each test case in EtherChannel and Flex Links test suites.

Table B-34 Average Network Convergence for Unicast and Multicast Test Streams

Test Case	BaseLine			200 MAC			400 MAC		
	Ucast MaxAvg (ms)	Mcast MaxAvg (ms)	App. Timeout	Ucast MaxAvg (ms)	Mcast MaxAvg (ms)	App. Timeout	Ucast MaxAvg (ms)	Mcast MaxAvg (ms)	App. Timeout
SEC8									
1- Shut	0.632	0.632	100%	0.345	0.678	100%	0.261	0.520	90%
2- No Shut	0.019	0.020	0%	0.012	0.041	10%	0.013	0.025	0%
3 - Disconnect	0.778	0.778	100%	0.508	0.661	100%	0.585	0.597	100%
4 - Reconnect	0.018	0.022	0%	0.012	0.019	0%	0.013	0.027	10%
7 - Stack Master Down	0.847	13.751	100%	0.814	10.617	100%	0.687	11.931	100%
8 - Switch reboot	0.131	17.611	100%	0.069	21.301	100%	0.062	14.002	100%
SEF8									
1- Shut	0.075	0.075	0%	0.039	0.076	0%	0.038	0.075	0%
2- No Shut	0.012	0.014	0%	0.006	0.018	0%	0.007	0.023	0%
3 - Disconnect	0.080	0.080	0%	0.044	0.087	0%	0.044	0.087	0%
4 - Reconnect	0.011	0.015	0%	0.006	0.018	0%	0.007	0.022	0%
7 - Stack Master Down	0.846	0.846	100%	0.624	0.848	100%	0.624	0.943	100%
8 - Switch reboot	0.021	15.744	100%	0.083	11.844	100%	0.077	18.302	100%
SFC8									
1- Shut	0.037	0.019	0%	0.055	0.021	0%	0.059	0.018	0%
2- No Shut	0.000	0.000	0%	0.000	0.000	0%	0.000	0.277	0%
3 - Disconnect	0.567	0.558	100%	0.571	0.559	100%	0.571	0.555	100%
4 - Reconnect	0.000	0.000	0%	0.000	0.000	0%	0.000	0.000	0%
7 - Stack Master Down	0.618	0.599	100%	0.647	0.645	100%	0.837	0.734	100%

Table B-34 Average Network Convergence for Unicast and Multicast Test Streams (continued)

Test Case	BaseLine			200 MAC			400 MAC		
	Ucast MaxAvg (ms)	Mcast MaxAvg (ms)	App. Timeout	Ucast MaxAvg (ms)	Mcast MaxAvg (ms)	App. Timeout	Ucast MaxAvg (ms)	Mcast MaxAvg (ms)	App. Timeout
8 - Switch reboot	0.000	0.000	0%	0.000	0.000	0%	0.000	0.000	0%
SFF8									
1- Shut	0.040	0.019	0%	0.037	0.023	0%	0.043	0.016	0%
2- No Shut	0.000	0.000	0%	0.000	0.000	0%	0.000	0.000	0%
3 - Disconnect	0.061	0.060	8%	0.048	0.046	0%	0.057	0.053	0%
4 - Reconnect	0.000	0.000	0%	0.000	0.000	0%	0.000	0.001	0%
7 - Stack Master Down	0.059	0.035	8%	0.063	0.037	0%	0.083	0.028	33%
8 - Switch reboot	0.000	0.000	0%	0.000	0.000	0%	0.000	1.019	0%

Figure B-4 shows the trend for physical cable-disconnection for the compared test suites with unicast test streams.

Figure B-4 Test case 3 - Disconnect Cable for RMF8, SMF8, SEF8 & SFF8 with Unicast Traffic

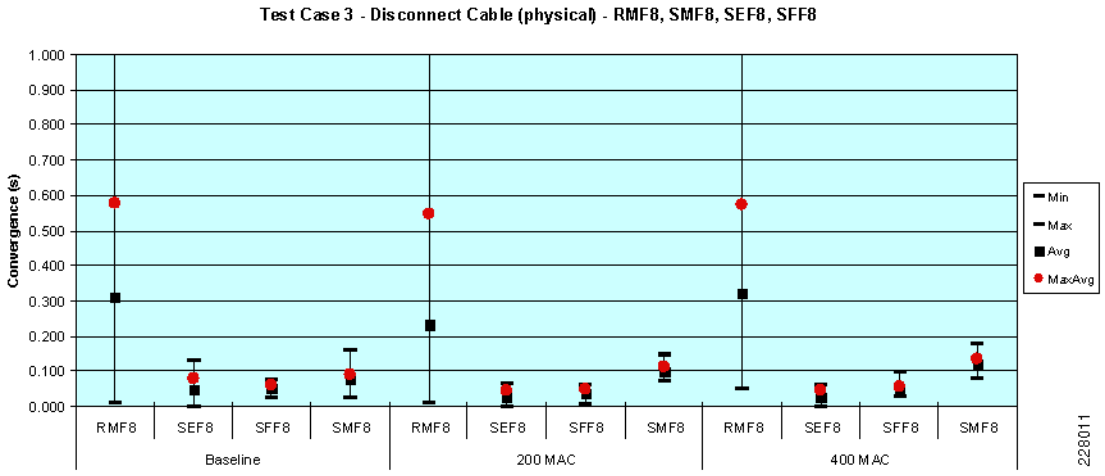
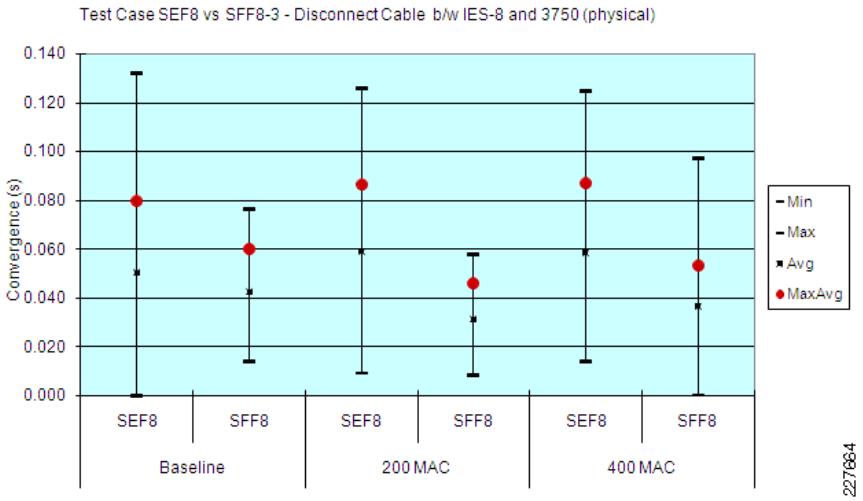


Figure B-5 shows the EtherChannel and Flex Links test results for test case 3 (disconnect cable with multicast test streams). In Figure B-5, the average network convergence is less than 100 ms, noting that in some test iterations the EtherChannel topology did converge >100 ms.

Figure B-5 Test Case 3 - Disconnect cable for SEF8 & SFF8 with Multicast Traffic



The key findings were as follows:

- In all key disruptions and recovery test cases, redundant star topologies with fiber uplinks and Flex Links converged the network quickly enough to consistently avoid time-critical application timeouts. In link disruption test cases, redundant star topologies with EtherChannel converged the network quickly enough to consistently avoid time-critical application timeouts.
  - EtherChannel was faster than Flex Links in converging unicast traffic with higher simulated end-devices, due to the use of both links.
  - EtherChannel had slower recovery in the StackMaster failure/recovery test cases with consistent application timeouts.
  - Flex Links was faster than EtherChannel in converging multicast traffic at all simulated end-device levels. EtherChannel on occasion converged slowly enough to trigger time critical I/O applications. Therefore, Cisco and Rockwell recommend Flex Links for redundant star topologies, although both are viable.
- For key all key disruptions, the ring topology converged more slowly than redundant star topologies, independent of resiliency protocols.
- In general, network convergence was fast enough in the reestablishing links and restoring a switch in the switch-stack test cases to avoid peer-to-peer application timeouts. This suggests restoring connectivity may not require planned downtime.

Media Analysis—Copper vs Fiber (RMC8 vs. RMF8 & SMC8 vs. SMF8)

This section compares the network convergence between copper and fiber uplinks when topologies (ring and redundant star) and resiliency protocol (MSTP) are the same, in 8-switch topologies based on peer-to-peer (UDP unicast) traffic streams. Only the link disruption test cases were compared as the other test cases were not conducted in all test suites (root switch failure) or not relevant (stack master failure) to the comparison. The results for the disconnect-cable were graphed to display the trend. This case was chosen to be the most representative of an outage. This section provides tables that compare the following:

- Minimum measured convergence of the set of test cases
- Maximum measured convergence of the set of test cases
- Average of the measure convergence time
- Average of the highest measured convergence from each test iteration (MaxAvg)

Table B-35 Test Case 1 - Bring link down (software) - RMC8, RMF8, SMC8, SMF8

Ucast	Baseline				200 MAC				400 MAC			
	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8
	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8
Min	0.380	0.051	0.010	0.011	0.397	0.051	0.022	0.031	0.394	0.063	0.034	0.046
Max	1.793	1.497	0.058	0.064	2.362	1.939	0.146	0.104	2.382	1.622	0.172	0.174
Avg	0.768	0.269	0.022	0.028	0.885	0.286	0.069	0.055	0.774	0.196	0.086	0.078
MaxAvg	0.977	0.467	0.032	0.043	1.104	0.464	0.106	0.077	0.990	0.318	0.128	0.103

Table B-36 Test Case 2 - Bring link up (software) - RMC8, RMF8, SMC8, SMF8-

Ucast	Baseline				200 MAC				400 MAC			
	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8
Min	0.007	0.007	0.010	0.010	0.013	0.007	0.019	0.019	0.022	0.021	0.020	0.030
Max	0.123	0.039	0.037	0.040	0.190	0.053	0.104	0.082	0.197	0.083	0.158	0.136
Avg	0.029	0.016	0.020	0.020	0.058	0.023	0.046	0.041	0.067	0.042	0.068	0.075
MaxAvg	0.052	0.028	0.030	0.029	0.098	0.043	0.072	0.062	0.109	0.061	0.111	0.119

Table B-37 Test Case 3 - Disconnect cable (physical) - RMC8, RMF8, SMC8, SMF8

Ucast	Baseline				200 MAC				400 MAC			
	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8
Min	0.380	0.007	0.387	0.024	0.386	0.007	0.401	0.072	0.393	0.048	0.415	0.080
Max	1.863	1.987	0.811	0.157	1.746	1.417	0.853	0.144	2.348	1.173	0.856	0.175
Avg	0.829	0.309	0.673	0.078	0.653	0.234	0.628	0.098	0.892	0.322	0.696	0.118
MaxAvg	1.118	0.575	0.677	0.091	0.745	0.545	0.646	0.111	1.157	0.575	0.720	0.136

Table B-38 Test Case 4 - Reconnect cable (physical) - RMC8, RMF8, SMC8, SMF8

Ucast	Baseline				200 MAC				400 MAC			
	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8	RMC8	RMF8	SMC8	SMF8
Min	0.008	0.007	0.010	0.010	0.016	0.007	0.019	0.020	0.021	0.022	0.030	0.030
Max	0.088	0.040	0.041	0.045	0.173	0.049	0.105	0.088	0.209	0.073	0.206	0.149
Avg	0.027	0.017	0.020	0.019	0.048	0.023	0.045	0.043	0.066	0.039	0.093	0.080
MaxAvg	0.050	0.030	0.029	0.028	0.085	0.043	0.070	0.064	0.110	0.057	0.156	0.129

Table B-39 Test Case 1 - Bring link down (software) - SEC8 vs. SEF8 & SFC8 vs. SFF8

Ucast	Baseline				200 MAC				400 MAC			
	SEC8	SEF8	SFC8	SFF8	SEC8	SEF8	SFC8	SFF8	SEC8	SEF8	SFC8	SFF8
Min	0.001	0.000	0.005	0.005	0.001	0.000	0.005	0.012	0.001	0.000	0.007	0.005
Max	0.815	0.097	0.073	0.068	0.425	0.051	0.179	0.057	0.417	0.049	0.140	0.065
Avg	0.317	0.040	0.028	0.030	0.173	0.020	0.038	0.030	0.131	0.019	0.038	0.030
MaxAvg	0.632	0.075	0.037	0.040	0.345	0.039	0.055	0.037	0.261	0.038	0.059	0.043

Table B-40 Test Case 2 - Bring link up (software) - SEC8 vs. SEF8 & SFC8 vs. SFF8

Ucast	Baseline				200 MAC				400 MAC			
	SEC8	SEF8	SFC8	SFF8	SEC8	SEF8	SFC8	SFF8	SEC8	SEF8	SFC8	SFF8
Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max	0.032	0.025	0.000	0.000	0.016	0.012	0.000	0.000	0.017	0.015	0.000	0.000
Avg	0.015	0.010	0.000	0.000	0.009	0.005	0.000	0.000	0.010	0.006	0.000	0.000
MaxAvg	0.019	0.012	0.000	0.000	0.012	0.006	0.000	0.000	0.013	0.007	0.000	0.000

Table B-41 Test Case 3 - Disconnect Cable (physical) - SEC8 vs. SEF8 & SFC8 vs. SFF8

Ucast	Baseline				200 MAC				400 MAC			
	SEC8	SEF8	SFC8	SFF8	SEC8	SEF8	SFC8	SFF8	SEC8	SEF8	SFC8	SFF8
Min	0.370	0.000	0.350	0.023	0.180	0.000	0.357	0.005	0.180	0.000	0.349	0.027
Max	0.795	0.132	0.770	0.075	0.787	0.063	0.762	0.058	0.791	0.062	0.767	0.097
Avg	0.581	0.051	0.563	0.052	0.368	0.026	0.565	0.039	0.389	0.026	0.563	0.049
MaxAvg	0.778	0.080	0.567	0.061	0.508	0.044	0.571	0.048	0.585	0.044	0.571	0.057

Table B-42 Test Case 4 - Reconnect cable (physical) - SEC8 vs. SEF8 & SFC8 vs. SFF8

Ucast	Baseline				200 MAC				400 MAC			
	SEC8	SEF8	SFC8	SFF8	SEC8	SEF8	SFC8	SFF8	SEC8	SEF8	SFC8	SFF8
Min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Max	0.028	0.023	0.000	0.000	0.015	0.013	0.000	0.000	0.018	0.014	0.000	0.000
Avg	0.014	0.009	0.000	0.000	0.009	0.005	0.000	0.000	0.010	0.006	0.000	0.000
MaxAvg	0.018	0.011	0.000	0.000	0.012	0.006	0.000	0.000	0.013	0.007	0.000	0.000

Figure B-6 shows the trend for physical cable disconnection (test case 3) for copper versus fiber for MSTP in both a ring and redundant star topology. In each case, the fiber topology converged significantly faster, usually in the range of 0.5 seconds. This is an expected result as the standards for copper media allow for more tolerance in identifying a link outage than in a fiber media.

Figure B-6 Disconnect cable RMC8, RMF8, SMC8 and SMF8

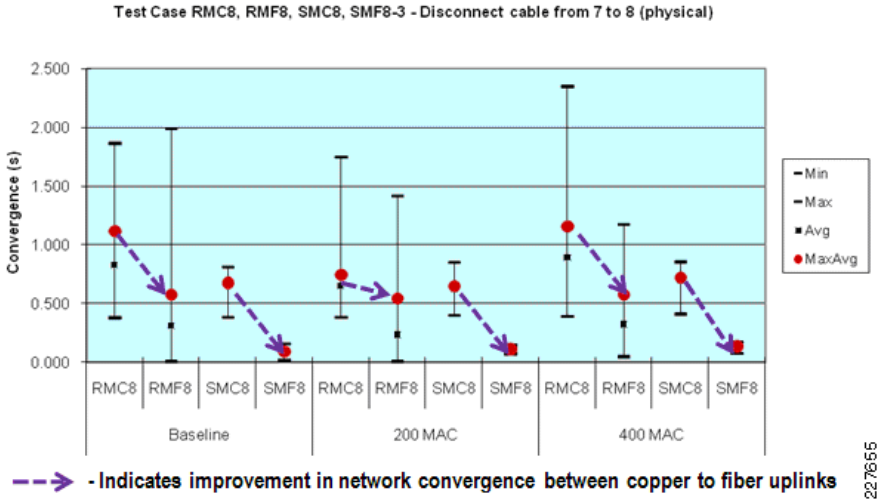
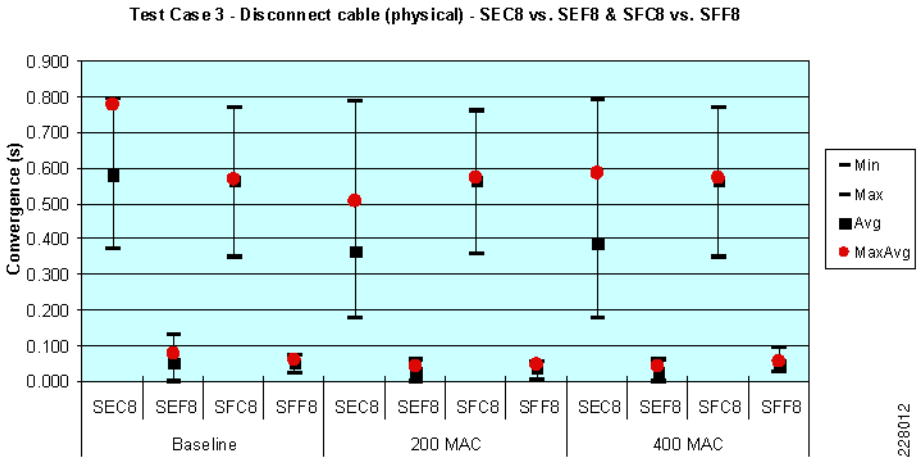


Figure B-7 shows the trend for network convergence after physical cable disconnection (test case 30) copper versus fiber in redundant star topologies with EtherChannel and Flex Link resiliency protocols. The impact of media type is more apparent with copper topologies converging nearly 0.5 seconds slower than fiber topologies.

Figure B-7 Disconnect cable SEC8 vs. SEF8 & SFC8 vs. SFF8



The key findings are as follows:

- In nearly all cases, fiber uplink topologies converged faster than copper uplink topologies, all other conditions being the same.

End-Devices (MAC Addresses) Impact Analysis

The analysis the impact the number of end-devices (or MAC addresses) have on the network is analyzed in this section. The analysis will review the trend based on the three MAC addresses cases tested: baseline, 200 MACs inserted, and 400 MACs inserted across the various test suites and test cases. The comparison is based on the "worst case convergence" result, which is the maximum measured convergence from each test run averaged for the set of test runs (MaxAvg). This section analyzes the test results for Spanning Tree test suites separately from the EtherChannel and Flex Links test suites.

End-Device Impact on Network Convergence for Spanning Tree Test Suites

This section provides relevant test results from each Spanning Tree test suite in which test runs were conducted with varying amounts of MAC addresses inserted by the network traffic generator. For each test suite, a table of the maximum measured convergence from each test iteration (MaxAvg) is used and a graph of those numbers is included.

Table B-43 RMC8 Network Convergence Averages

RMC8 - End-Device Analysis	MaxAvg (ms)		
	Baseline	200 MAC	400 MAC
TC 1 Shut	0.977	1.104	0.990
TC 2 No Shut	0.052	0.098	0.109
TC 3 Disconnect	1.118	0.745	1.157
TC 4 Reconnect	0.050	0.085	0.110
TC 5 Root Down	0.759	0.752	0.959
TC 6 Root Up	0.489	0.388	0.463
TC 7 Stk Mstr down	0.809	0.895	0.857
TC 8 Swtich up	0.055	0.079	0.086

Figure B-8 RMC8 Trend of MAC Address Impact on Network Convergence

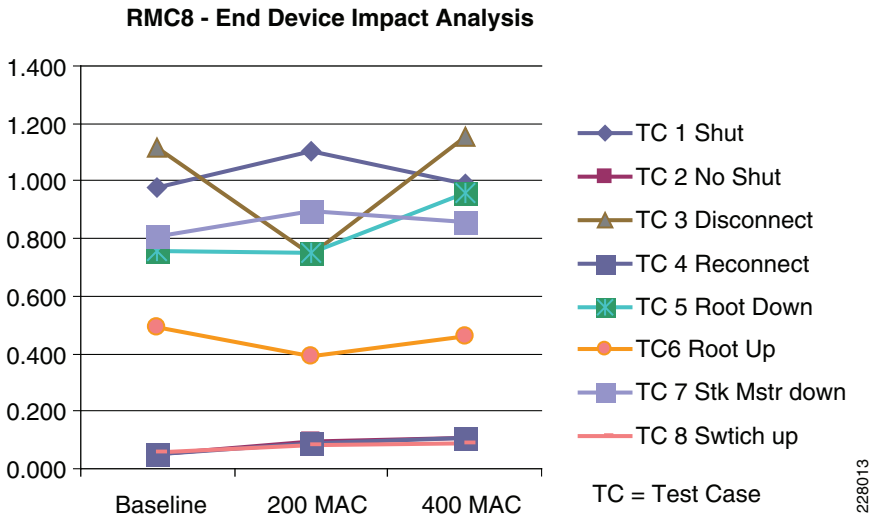


Table B-44 RMC16 Network Convergence Averages

RMC16 – Test Cases	MaxAvg(ms)		
	Baseline	200 MAC	400 MAC
TC 1 Shut	1.794	1.656	1.670
TC 2 No Shut	0.022	0.038	0.053
TC 3 Disconnect	1.416	1.064	1.413
TC 4 Reconnect	0.029	0.035	0.057
TC 5 Root Down	0.978	0.871	0.655
TC6 Root Up	0.499	0.444	0.465
TC 7 Stk Mstr down	0.936	1.036	0.991
TC 8 Swtich up	0.020	0.031	0.041

Figure B-9 RMC16 Trend of MAC Address Impact on Network Convergence

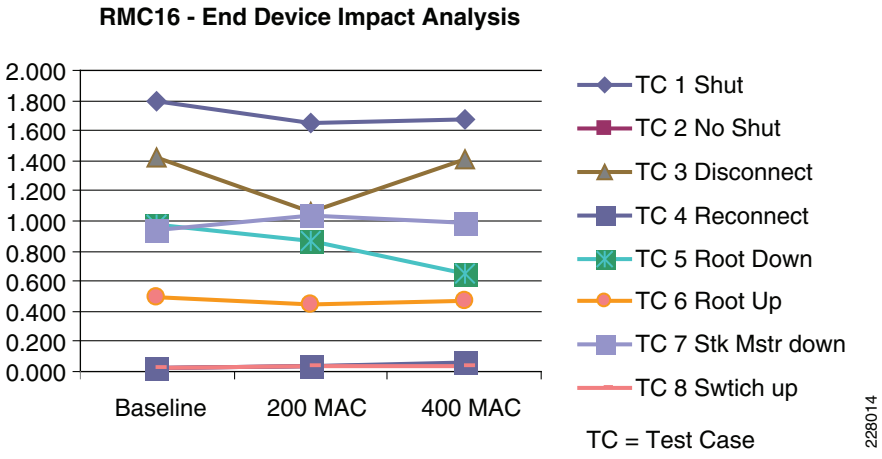


Table B-45 RMF8 Network Convergence Averages

RMF8 – Test Cases	MaxAvg (ms)		
	Baseline	200 MAC	400 MAC
TC 1 Shut	0.467	0.464	0.318
TC 2 No Shut	0.028	0.043	0.061
TC 3 Disconnect	0.575	0.545	0.575
TC 4 Reconnect	0.030	0.043	0.057

Figure B-10 RMF8 Trend of MAC Address Impact on Network Convergence

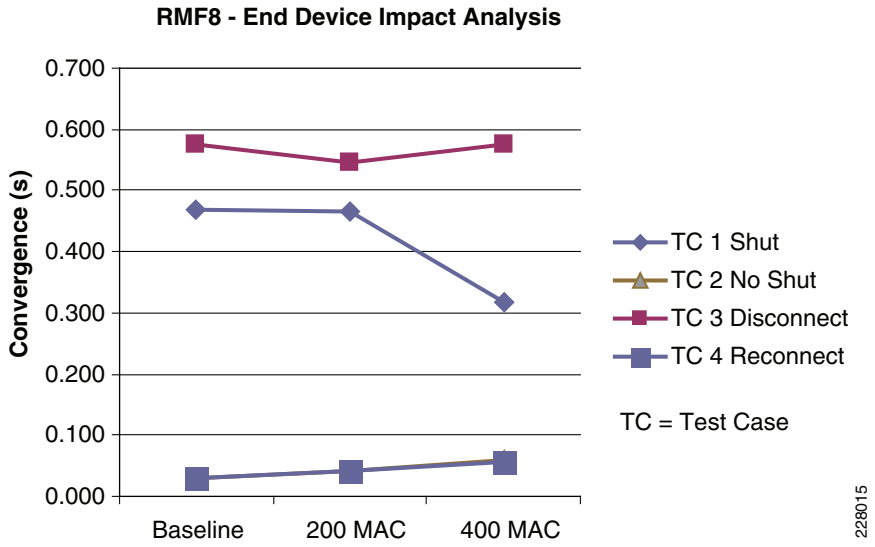


Table B-46 SMC8 Network Convergence Averages

SMC8 - End-Device Analysis	MaxAvg (ms)		
	Baseline	200 MAC	400 MAC
TC 1 Shut	0.032	0.106	0.128
TC 2 No Shut	0.030	0.072	0.111
TC 3 Disconnect	0.677	0.646	0.720
TC 4 Reconnect	0.029	0.070	0.156
TC 5 Stk Mstr down	0.786	0.796	0.865
TC 6 Swtich up	0.132	0.117	0.175

Figure B-11 SMC8 Trend of MAC Address Impact on Network Convergence

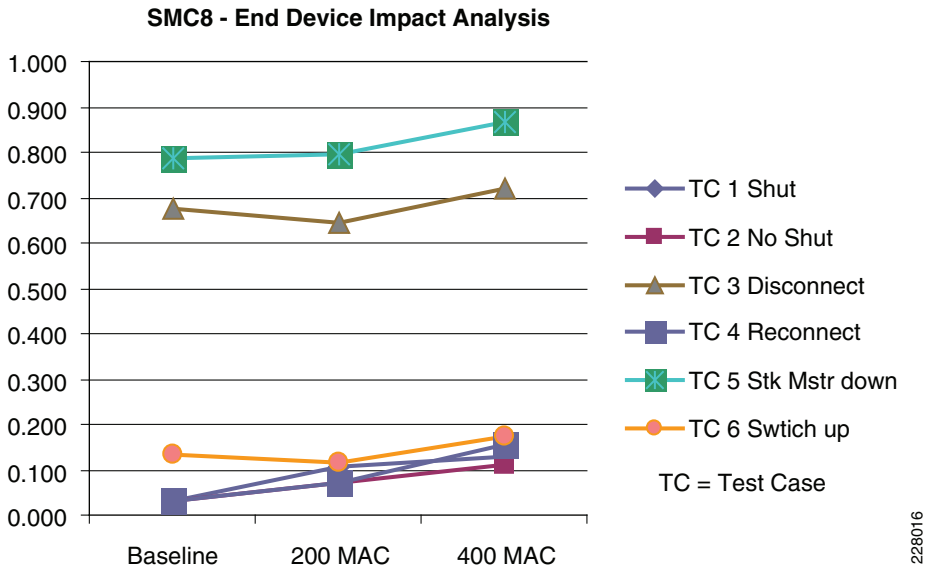
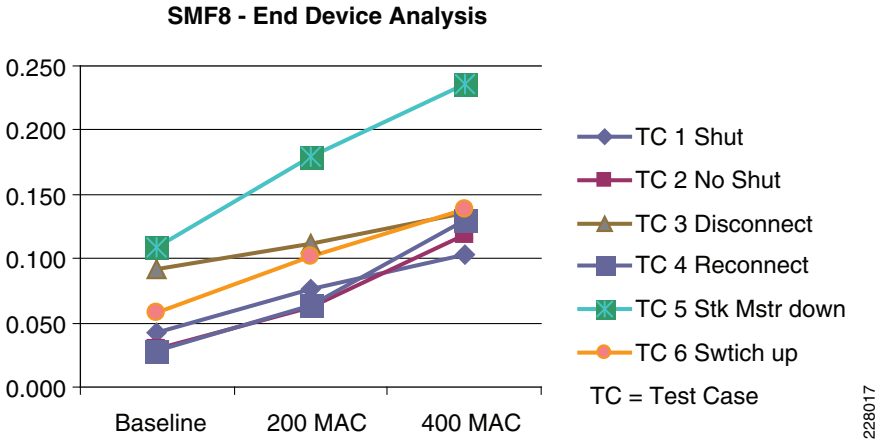


Table B-47 SMF8 Network Convergence Averages

SMF8 - Test Case	MaxAvg (ms)		
	Baseline	200 MAC	400 MAC
TC 1 Shut	0.043	0.077	0.103
TC 2 No Shut	0.029	0.062	0.119
TC 3 Disconnect	0.091	0.111	0.136
TC 4 Reconnect	0.028	0.064	0.129
TC 5 Stk Mstr down	0.109	0.180	0.236
TC 6 Swtich up	0.058	0.101	0.138

Figure B-12 SMF8 Trend of MAC Address Impact on Network Convergence



Based on the above graphs, only SMF8 shows a clear trend of increasing network convergence with increasing number of MAC addresses. Based on how STP works and the need to rebuild switching tables (which are MAC-based), there is an expectation that the number of MAC addresses increases the network convergence. The fact that this result is best seen in this test is explained in

that redundant star with fiber uplinks has the lowest network convergence, where the MAC address impact is more readily observed. The tests suggest that this impact is not as significant as the media uplink and topology considerations and is somewhat overshadowed by the variance introduced by the topology and media uplink (especially copper).

End-Device Impact on Network Convergence for EtherChannel and FlexLinks Test Suites

This section provides relevant test results from each EtherChannel and Flex Links test suite, where test runs were conducted with varying amounts of MAC addresses inserted by the network traffic generator. For each test suite, a table of the maximum measured convergence from each test iteration (MaxAvg) and a graph of those numbers are included.

Table B-48 SEC8 Network Convergence Averages

SEC8 - Test Cases	MaxAvg (ms)		
	Baseline	200 MAC	400 MAC
TC 1 Shut	0.632	0.345	0.261
TC 2 No Shut	0.019	0.012	0.013
TC 3 Disconnect	0.778	0.508	0.585
TC 4 Reconnect	0.018	0.012	0.013
TC 5 Stk Mstr down	0.847	0.814	0.687
TC 6 Swtich up	0.131	0.069	0.062

Figure B-13 SEC8 Trend of MAC Address Impact on Network Convergence

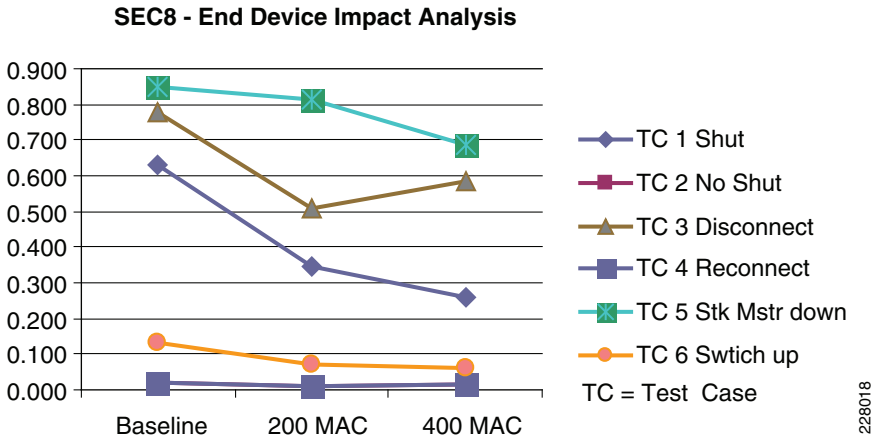


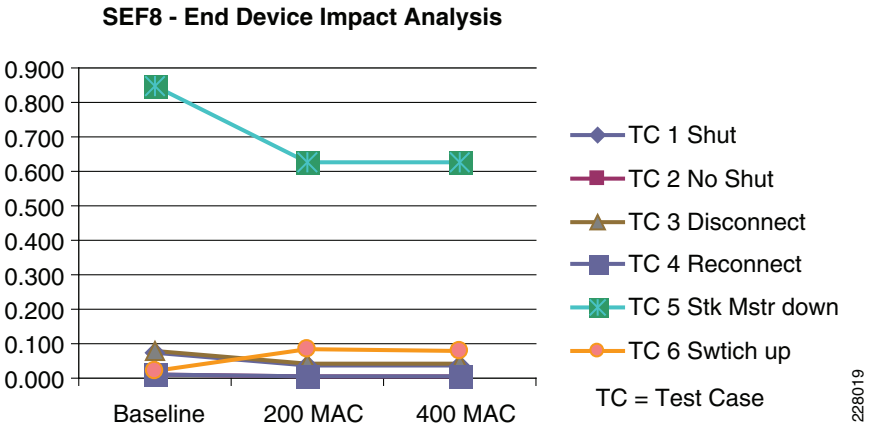
Table B-49 SEF8 Network Convergence Averages

SEF8 - Test Case	Network Convergence (ms)		
	Baseline	200 MAC	400 MAC
TC 1 Shut	0.075	0.039	0.038
TC 2 No Shut	0.012	0.006	0.007
TC 3 Disconnect	0.080	0.044	0.044
TC 4 Reconnect	0.011	0.006	0.007

Table B-49 SEF8 Network Convergence Averages (continued)

SEF8 - Test Case	Network Convergence (ms)		
	Baseline	200 MAC	400 MAC
TC 5 Stk Mstr down	0.846	0.624	0.624
TC 6 Swtich up	0.021	0.083	0.077

Figure B-14 SEF8 Trend of MAC Address Impact on Network Convergence



In the above EtherChannel examples, the test cases with link disruption (TC1 and TC2) showed the baseline, one MAC address in the measured test streams, to have a higher network convergence than in the other cases. That is to be expected as the link disrupted was the link on which the EtherChannel load balancing (based on source MAC address) was choosing for those single-MAC test streams. In the other test streams, the EtherChannel load balancing was balancing the traffic across both available links as multiple MAC addresses were used in the test streams, thereby lowering the measured network convergence as some of the traffic is not impacted by the link loss.

Table B-50 SFC8 Network Convergence Averages

SFC8 - Test Case	MaxAvg (ms)		
	Baseline	200 MAC	400 MAC
TC 1 Shut	0.037	0.055	0.059
TC 2 No Shut	0.000	0.000	0.000
TC 3 Disconnect	0.567	0.571	0.571
TC 4 Reconnect	0.000	0.000	0.000
TC 5 Stk Mstr down	0.618	0.647	0.837
TC 6 Swtich up	0.000	0.000	0.000

Figure B-15 SFC8 Trend of MAC Address Impact on Network Convergence

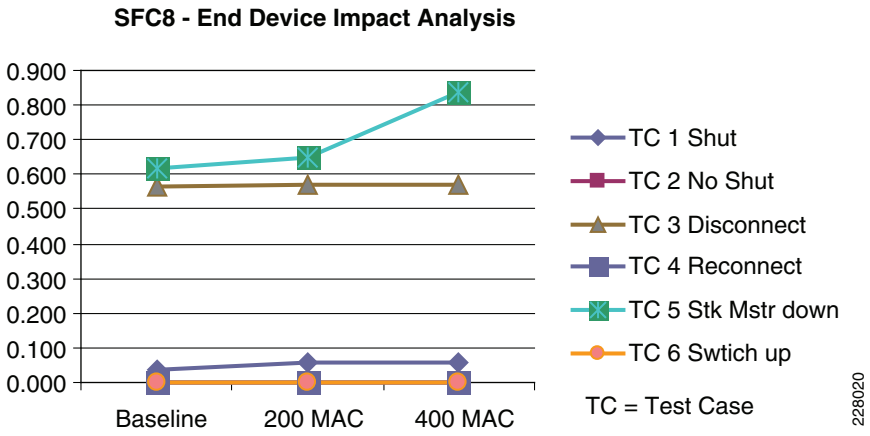
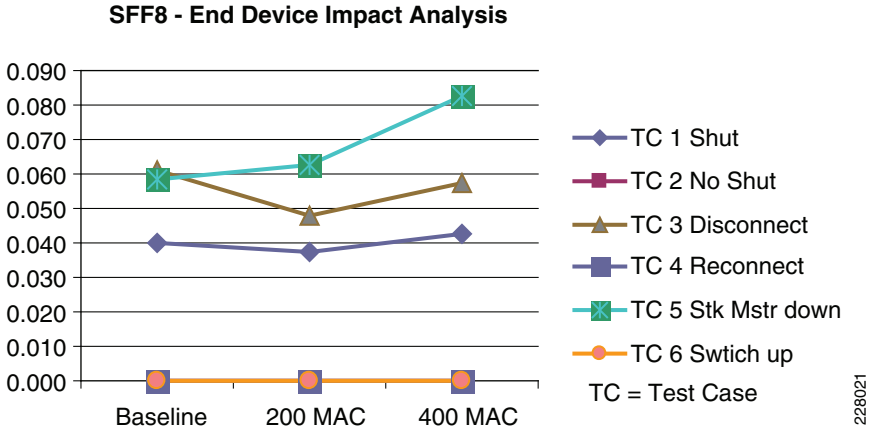


Table B-51 SFF8 Network Convergence Averages

SFF8 - Test Case	MaxAvg (ms)		
	Baseline	200 MAC	400 MAC
TC 1 Shut	0.040	0.037	0.043
TC 2 No Shut	0.000	0.000	0.000
TC 3 Disconnect	0.061	0.048	0.057
TC 4 Reconnect	0.000	0.000	0.000
TC 5 Stk Mstr down	0.059	0.063	0.083
TC 6 Swtich up	0.000	0.000	0.000

Figure B-16 SFF8 Trend of MAC Address Impact on Network Convergence



Based on the above figures, the number of end-devices has little or no impact on the network convergence. Based on how Flex Links and EtherChannel work and that no specific switching tables are rebuilt after a network event, there is an expectation that the number of MAC addresses has limited impact on the network convergence. In fact, in EtherChannel, due to the load balancing across the multiple links based on MAC address (either source or destination), a stream with a single MAC address versus with many MAC addresses converged more slowly as only one link is used to carry the stream with a single MAC address.

Note that this does not take into consideration an increase in overall network traffic, as the test streams used were at a constant packets per second rate.

The key findings are as follows:

- Simulated end-devices increased network convergence in Spanning Tree configurations, although this impact is outweighed by media uplink and topology impacts.
- Simulated end-devices, at the levels tested, did not have a significant impact on EtherChannel and Flex Links topologies.

Restore Impact Analysis

This section analyzes the network convergence and application timeout percentage for the restore test cases in each test suite. The test cases include the following:

- Test Case 2—No Shut Link
- Test Case 4—Reconnect Cable
- Test Case 8—Switch Reboot

Table B-52 Restore Impact Analysis

Test Case	BaseLine		200 MAC		400 MAC	
	Max Avg (ms)	App. Timeout	MaxAvg (ms)	App. Timeout	MaxAvg (ms)	App. Timeout
RMC8*						
2- No Shut	0.052	45%	0.098	50%	0.109	50%
4 - Reconnect	0.050	45%	0.085	50%	0.110	50%
8 - Switch reboot	0.055	60%	0.079	50%	0.086	50%
RMC16						
2- No Shut	0.022	0%	0.038	0%	0.053	0%
4 - Reconnect	0.029	0%	0.035	0%	0.057	0%
8 - Switch reboot	0.020	8%	0.031	0%	0.041	0%
RPC8						
2- No Shut	0.028	0%				
4 - Reconnect	0.030	0%				
8 - Switch reboot	0.024	0%				
RMF8						
2- No Shut	0.028	30%	0.043	0%	0.061	0%
4 - Reconnect	0.030	0%	0.043	0%	0.057	0%
SMC8						
2- No Shut	0.030	0%	0.072	50%	0.111	100%
4 - Reconnect	0.029	0%	0.070	50%	0.156	100%
8 - Switch reboot	0.132	10%	0.117	70%	0.175	100%
SMF8						
2- No Shut	0.029	0%	0.062	30%	0.119	50%
4 - Reconnect	0.028	0%	0.064	20%	0.129	90%
8 - Switch reboot	0.058	0%	0.101	50%	0.138	70%
SEC8						
2- No Shut	0.019	0%	0.012	10%	0.013	0%
4 - Reconnect	0.018	0%	0.012	0%	0.013	10%

Table B-52 Restore Impact Analysis (continued)

Test Case	BaseLine		200 MAC		400 MAC	
	Max Avg (ms)	App. Timeout	MaxAvg (ms)	App. Timeout	MaxAvg (ms)	App. Timeout
8 - Switch reboot	0.131	100%	0.069	100%	0.062	100%
SEF8						
2- No Shut	0.012	0%	0.006	0%	0.007	0%
4 - Reconnect	0.011	0%	0.006	0%	0.007	0%
8 - Switch reboot	0.021	100%	0.083	100%	0.077	100%
SFC8						
2- No Shut	0.000	0%	0.000	0%	0.000	0%
4 - Reconnect	0.000	0%	0.000	0%	0.000	0%
8 - Switch reboot	0.000	0%	0.000	0%	0.000	0%
SFF8						
2- No Shut	0.000	0%	0.000	0%	0.000	0%
4 - Reconnect	0.000	0%	0.000	0%	0.000	0%
8 - Switch reboot	0.000	0%	0.000	0%	0.000	0%

In one RMC8 testing environment, the safety I/O devices were configured to timeout in much less than 100 ms, causing the increase in application timeouts. In this test suite, the measured average network convergence suggests much fewer time-critical application timeouts would have been measured if the devices were configured differently.

The key findings are as follows:

- The restore test cases generally converged quickly enough to avoid time-critical application timeouts, with a few exceptions.
- EtherChannel topologies did not converge quickly enough after switch reboots to avoid time-critical application time outs.
- Redundant star Spanning Tree topologies did not converge quickly enough in high-MAC address (simulated end clients) to avoid significant application time outs.

Application Latency (Screw-to-Screw) Analysis

The various test runs of the screw-to-screw tests are summarized in Table B-53. The table shows that the application latency and jitter due to additional IE switches are relatively insignificant compared to the overall IACS network application latency and jitter. The additional latency per-switch hop was approximately 10 µs in the test cases. Table B-53 lists the test results from the screw-to-screw test runs.

Table B-53 Screw-to-Screw

	Short-Path				Long-Path				Analysis	
Test Suite	No. of hops	Avg. (ms)	Min (ms)	Max (ms)	No. of hops	Avg. (ms)	Min (ms)	Max (ms)	Delta (ms)	Latency per hop (ms)
RMC8	2	13.045	2.175	25.100	9	13.111	2.200	25.025	0.066	0.009
	2	13.143	2.225	25.200	9	13.183	2.275	25.976	0.040	0.006
RMC16	2	13.035	2.175	24.824	17	13.185	2.175	24.825	0.150	0.010
	2	13.136	2.250	24.924	17	13.303	2.250	25.325	0.167	0.011

Table B-53 Screw-to-Screw (continued)

	Short-Path				Long-Path				Analysis	
Test Suite	No. of hops	Avg. (ms)	Min (ms)	Max (ms)	No. of hops	Avg. (ms)	Min (ms)	Max (ms)	Delta (ms)	Latency per hop (ms)
RMF8	2	13.036	2.175	24.849	9	13.108	2.175	60.076	0.072	0.010
	2	13.148	2.225	25.151	9	13.220	2.250	26.300	0.072	0.010
SMC8	3	13.044	2.225	24.825						
	3	13.175	2.275	24.900	3	13.183	2.275	25.975		
SMF8	3	13.036	2.200	24.825						
SEC8	3	13.045	2.200	24.826	3	13.035	2.200	24.849		
SEF8	3	13.061	2.172	24.825	3	13.134	2.225	26.199		
	3	13.165	2.251	24.899	3	13.169	2.250	25.175		

The key findings are as follows:

- The conclusion is that latency and jitter introduced by additional network infrastructure is not significant to I/O type of applications