APPENDIX A

Characterization of the EttF Cell/Area Zone Design

All factory floor devices are connected at the cell/area zone layer of EttF 1.1. From a network design perspective, a solid spanning tree and multicast design are critical for reliability and to meet predefined service-level agreements (SLAs). As mentioned in earlier sections, Cisco recommends that Rapid Spanning Tree Protocol (RSTP 802.1w) and IGMP snooping with querier be deployed at this layer. This appendix outlines the validation methodology and the corresponding results of the testing.

STP Testing

STP Test Methodology

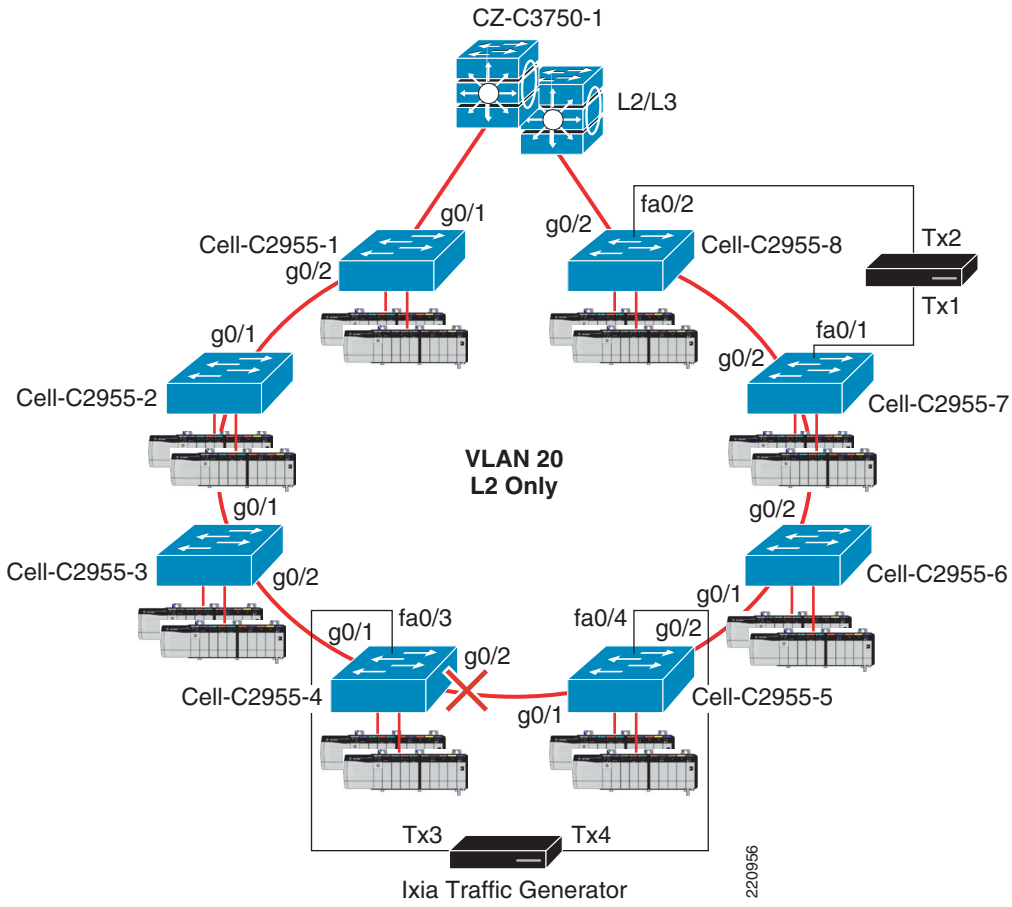
Eight Cisco Catalyst 2955 switches, each running Native IOS 12.1(22)EA9, plus one Catalyst 3750 running Native IOS 12.2(25)SEB4, are linked together in back-to-back fashion via 802.1q Gigabit Ethernet trunks to form a ring topology (See Figure A-1).

All nine devices are running RSTP 802.1w carrying only one VLAN (vlan 20). This topology creates a Layer 2 loop, and therefore one port must be blocked by STP. By configuring switch CZ-3750-1 with the lowest spanning tree priority, it is elected as the root bridge for this VLAN. The STP parameters on all the other switches are left at their default settings. Accordingly, switch Cell-2955-4 is now the furthest away from the root bridge in terms of path cost and must select a port to block (GigabitEthernet 0/2). The root port on devices Cell-2955-1 through Cell-2955-4 is GigabitEthernet 0/1, and the root port on devices Cell-2955-5 through Cell-2955-8 is GigabitEthernet 0/2. A traffic generator (Ixia 400 Tf) is attached to switches Cell-2955-7, Cell-2955-8, Cell-2955-4, and Cell-2955-5 via ports Tx1, Tx2, Tx3, Tx4 respectively. The traffic generator is used to measure the convergence time in various failure scenarios.

STP Test Topology

Figure A-1 shows the test topology.

Figure A-1 Test Topology



Multiple bidirectional traffic streams are configured on Ixia between Tx1 <-> Tx2 and Tx3 <-> Tx4. Each of these pairs is referred to as a traffic suite with their own test cases. Each stream for each test suite is designed to source 1, 50, 100, and 200 MAC addresses destined to 1, 50, 100, and 200 MAC addresses. Thus, twice the number of configured source MAC addresses are traversing the ring for each test case. Each packet is a mix of 500 and 64 bytes in length sent in a continuous fashion until the STP has re-converged and the network has stabilized. At steady state for Suite 1 (Tx1 <-> Tx2), the traffic flow is as follows:

1. Packet egresses Tx1 of Ixia and ingresses port fa0/1 of Cell-2955-7
2. Packet then egresses gi0/2 on Cell-2955-7 and ingresses port g0/1 on Cell-C2955-8
3. Packet then egresses fa0/2 on Cell-C2955-8 and finally ingresses Tx2 of Ixia

This flow is reversed for streams going in the opposite direction (Tx2 to Tx1).

At steady state for Suite 2 (Tx3 <-> Tx4), the traffic flow is as follows:

1. Packet egresses Tx3 of Ixia and ingresses port fa0/3 of Cell-C2955-4

2. Because STP is blocking port gi0/2, the packet egresses gi0/1 of Cell-C2955-4 and traverses the entire ring in the clockwise direction until it reaches Cell-C2955-5
3. Packet ingresses gi0/2 on Cell-C2955-5 and egresses fa0/4
4. Packet finally ingresses Tx4 of Ixia

This flow is reversed for streams going in the opposite direction (Tx4 to Tx3).

STP Test Scenarios

Two test suites are explored, each with a different traffic flow. Within each test suite, multiple failure scenarios are introduced to simulate various STP changes in the ring topology. With each failure, convergence time is measured using the following formula:

[(Tx - Rx) / packet rate] * 1000

Where:

Tx = Packets transmitted

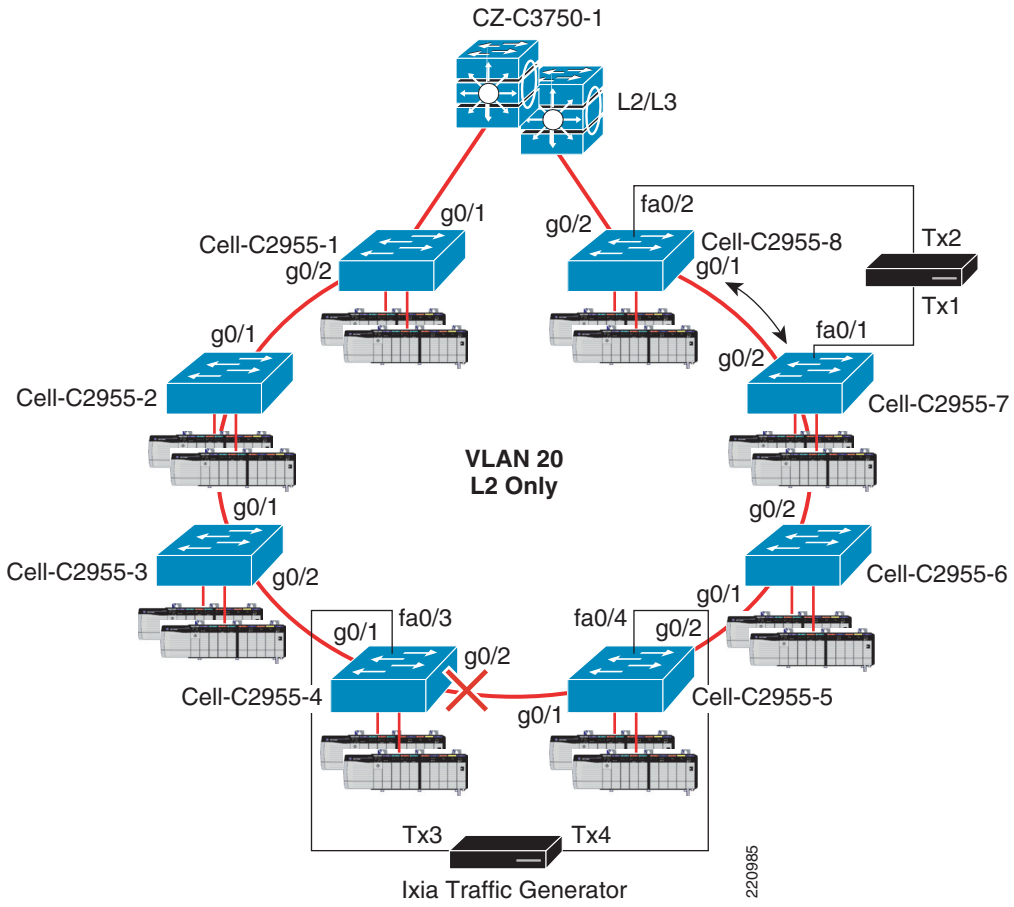
Rx = Packets received

PPS = 10,000 pps

Test Suite 1—Bidirectional Traffic (Tx1 <-> Tx2)

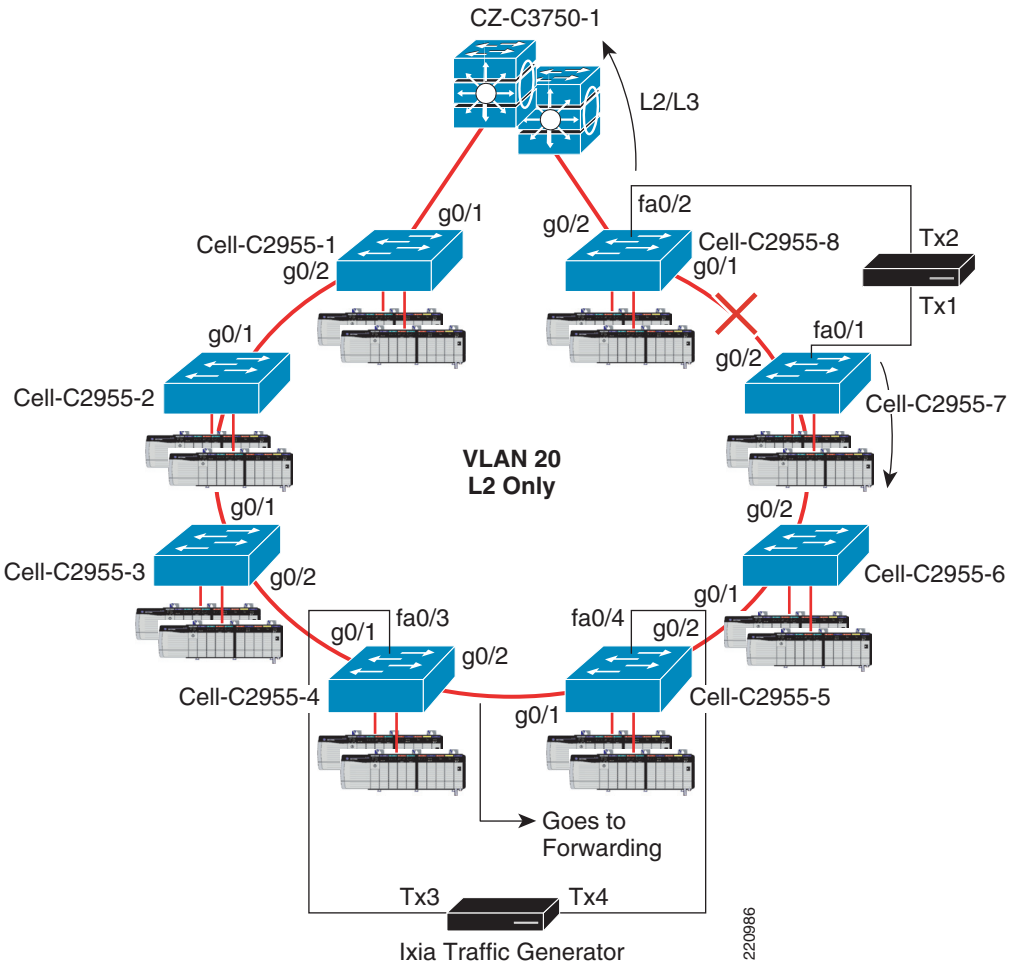
At steady state, traffic is flowing bidirectionally point-to-point between Cell-C2955-7 and Cell-C2955-8 (essentially a best-case scenario). (See Figure A-2.)

Figure A-2 Test Suite 1—Bidirectional Traffic Flow



However, after simulating a failure between these two switches, the traffic must then traverse the entire ring (becoming the worst-case scenario) to reach its destination. (See Figure A-3.)

Figure A-3 Test Suite 1—Worse-Case Scenario



The eight failure scenarios in Suite 1 are as follows:

- Failure 1—Software shut link between Cell-C2955-7 and Cell-C2955-8
- Failure 2—Software unshut link between Cell-C2955-7 and Cell-C2955-8
- Failure 3—Physically remove link between Cell-C2955-7 and Cell-C2955-8
- Failure 4—Physically re-insert link between Cell-C2955-7 and Cell-C2955-8
- Failure 5—Root bridge down
- Failure 6—Root bridge up
- Failure 7—Stack master down on CZ-C3750
- Failure 8—Stack master re-established on CZ-C3750

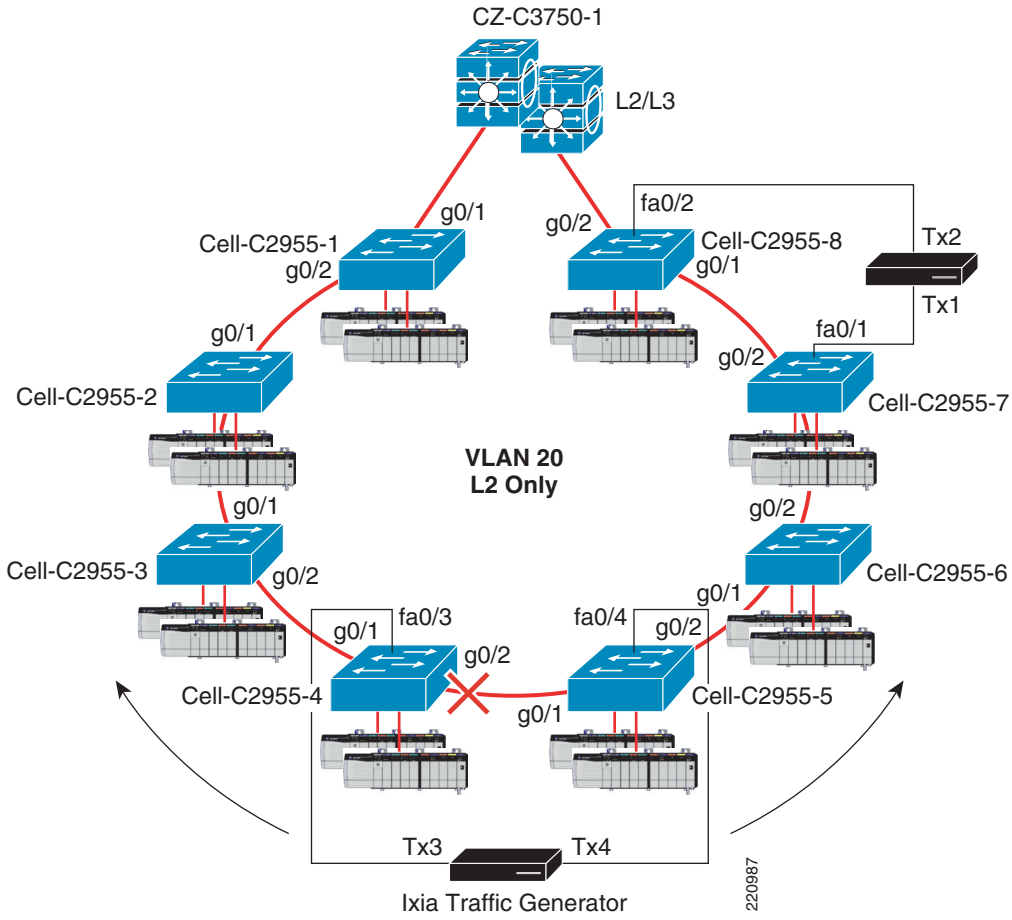
For each failure scenario, the following is measured and verified:

- Convergence time
- Verify Rockwell Automation (RA) equipment functioning properly after disruption
- Measure CPU and memory on cell devices that are sending and receiving Ixia traffic

Test Suite 2—Bidirectional Traffic (Tx3 <-> Tx4)

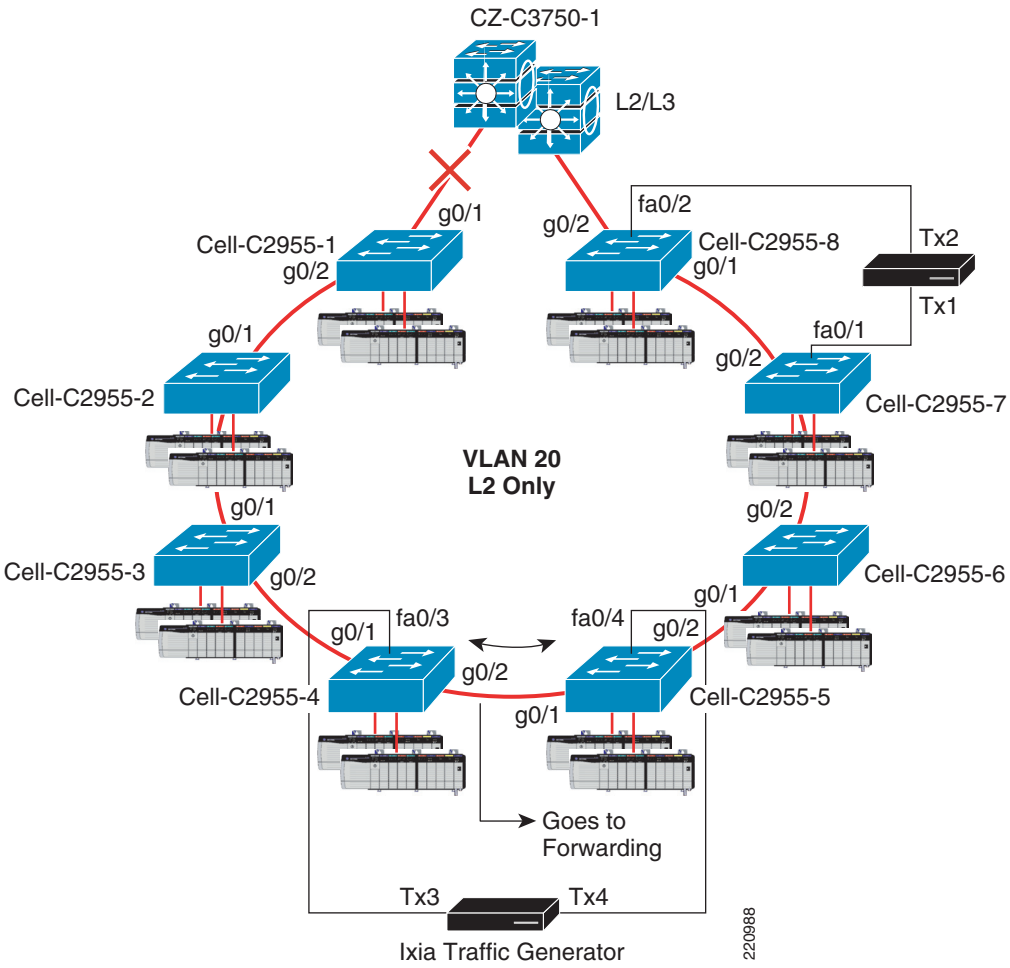
At steady state, traffic is flowing bidirectionally between Cell-C2955-4 and Cell-C2955-5 across the entire ring. (See Figure A-4.)

Figure A-4 Test Suite 2—Bidirectional Traffic Flow



Because STP is blocking gi0/2 on Cell-C2955-4, this constitutes the worse-case scenario before any failures are introduced. However, after a network failure and a subsequent STP topology change, traffic flows to its directly-connected neighbor and becomes the best-case scenario. (See Figure A-5.)

Figure A-5 Test Suite 2—Best-Case Scenario



The eight failure scenarios in Suite 2 are as follows:

- Failure 1—Software shut link between Cell-C2955-1 and CZ-C3750
- Failure 2—Software unshut link between Cell-C2955-1 and CZ-C3750
- Failure 3—Physically remove link between Cell-C2955-1 and CZ-C3750
- Failure 4—Physically re-insert link between Cell-C2955-1 and CZ-C3750
- Failure 5—Root bridge down
- Failure 6—Root bridge up
- Failure 7—Stack master down on CZ-C3750
- Failure 8—Stack master re-established on CZ-C3750

For each failure scenario, the following is measured and verified:

- Convergence time
- Verify RA equipment functioning properly after disruption
- Measure CPU and memory on cell devices that are sending and receiving Ixia traffic

Test Tools

The following equipment is needed for performing these tests.

- 16 Cisco Catalyst C2955T-12 industrial switches
- 2 Cisco Catalyst WS-C3750G-24PS (stacked)
- 1 Ixia traffic generator
- 1 set of RA equipment

STP Test Results

Suite 1 Test Cases

Table A-1 Test Case 1—Software Shut Link between Cell-C2955-7 and Cell-C2955-8

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	444.92	446.60	1105.3	1107.4	1436.7	1488	2015	2017.1
2	408.744	410.49	1362.5	1364.5	1264	1266.1	1750.5	1747.5
3	319.11	320.81	1080.6	1082.6	1064	1066	1027.4	1029.4
Avg	390.9252242	392.6380775	1182.8	1184.833333	1254.9	1273.366667	1597.633333	1598

Table A-2 Test Case 2—Software Unshut Link between Cell-C2955-7 and Cell-C2955-8

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	229.29	232.18	790.9	802.7	1990.6	2005.4	2005.4	1486.9
2	171.02	174.62	992.3	1002.9	1993.2	2004.8	2004.8	1584.6
3	314.75	317.79	993.6	1003.5	1987.9	2005.9	2005.9	1981.7
Avg	238.35	241.53	925.60	936.37	1990.57	2005.37	2005.37	1817.73

Table A-3 Test Case 3—Physically Remove Link between Cell-C2955-7 and Cell-C2955-8

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	511.44	510.21	2071.7	2071.7	1738.3	1738.3	2140.6	2140.6
2	465.48	462.35	2197.5	2197.5	1970.6	1970.6	2505.1	2505.1
3	441.89	439.76	1952.6	1952.6	2040.6	2110.2	1803	1803
Avg	472.94	470.77	2073.93	2073.93	1916.5	1939.7	2149.57	2149.57

Table A-4 Test Case 4—Physically Re-insert Link between Cell-C2955-7 and Cell-C2955-8

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	174.017	175.616	1810.6	1822.6	1989.9	2001	1979.3	1989.8
2	474.074	473.718	1989.7	2002.3	1863	1879.1	1986.3	2003.1
3	473.340	473.079	1992.1	2004.1	1968.3	2001.1	1891.7	1916.8
Avg	407.143	407.471	1930.8	1943	1940.4	1960.40	1952.43	1969.9

Table A-5 Test Case 5—Root Bridge Down

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
Avg	0	0	0	0	0	0	0	0

Table A-6 Test Case 6—Root Bridge Up

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	173.03	174.24	809.5	795.7	898.2	879.5	923.6	899.9
2	57.83	55.93	863.3	848.7	733.1	715.2	912.5	882.7
3	82.74	80.09	743	726.9	857.5	836.8	853.9	838.3
Avg	104.53	103.42	805.27	790.43	829.6	810.50	896.67	873.63

Table A-7 Test Case 7—Stack Master Down on CZ-C3750

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	8.3	13.40	16.1	25.6	14.1	28.6	28.7	31.2
2	9.8	15.49	16.3	24.3	14.8	26.6	22.7	28.2
3	8.6	15.40	16.7	23.3	11.1	25.6	25.7	30.2
Avg	8.90	14.76	16.37	24.40	13.33	26.93	25.70	29.87

Table A-8 Test Case 8—Stack Master Re-Established on CZ-C3750

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	153.10	145.19	982.5	968.6	919.2	898	883.2	865.3
2	155.10	148.19	891.8	859.6	949.2	924.5	984.2	978.2
3	161.39	161.39	851.8	895.6	986.9	974.7	927.3	915.4
Avg	156.53	151.59	908.70	907.93	951.77	932.40	931.57	919.63

Suite 2 Test Cases

Table A-9 Test Case 1—Software Shut Link between Cell-C2955-1 and CZ-C3750

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	29.60	48.00	43	50.1	51.5	56.5	73.3	95.3
2	32.60	43.49	39.1	46.1	47.2	59.8	68.3	90.7
3	39.70	54.79	45.1	47.2	45	57.4	66.2	88.3
Avg	38.20	48.06	42.4	47.8	47.9	57.9	69.26	91.43

Table A-10 Test Case 2—Software Unshut Link between Cell-C2955-1 and CZ-C3750

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	1275.3	1289.054069	1944.6	1956.2	1923.7	1934.2	1916.8	1942.6
2	1361.1	1377.855617	1954	1965.7	1981.6	1987.5	1999.9	1964.8
3	1469.7	1475.2	1940.1	1951.3	1927.7	1933.8	1909.1	1930.7
Avg	1368.7	1380.703229	1946.233333	1957.733333	1944.333333	1951.833333	1941.933333	1946.033333

Table A-11 Test Case 3—Physically Remove Link between Cell-C2955-1 and CZ-C3750

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	537.4	537.5	474.8	480	570.4	575	492.3	512.3
2	511.6	511.7	526.3	526.1	519.6	529.7	567.2	587.4
3	423.6	423.7	497.6	497.2	492.1	510.2	571.2	576.6
Avg	490.8666667	490.9666667	499.5666667	501.1	527.3666667	538.3	543.5666667	558.7666667

Table A-12 Test Case 4—Physically Re-insert Link between Cell-C2955-1 and CZ-C3750

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	1964.9	1970.8	1983.2	1991.3	1924.5	1938.2	1928.5	1946.4
2	1971.1	1976.9	1965.2	1974.5	1925.3	1939.3	1883.1	1894.5
3	1980.9	1986.5	1950.3	1957.6	1982.5	1962.2	1950.3	1992.1
Avg	1972.3	1978.066667	1966.233333	1974.466667	1944.1	1946.566667	1920.633333	1944.333333

Table A-13 Test Case 5—Root Bridge Down

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	466.4	466.6	539.1	544.3	580.7	591	859.5	862.3
2	477	477.2	529.1	534.3	797.3	797.8	1034.9	822.6
3	424.4	424.9	556.6	556	790.3	788.4	767.5	787.9
Avg	455.9333333	456.2333333	541.6	544.8666667	722.7666667	725.7333333	887.3	824.2666667

Table A-14 Test Case 6—Root Bridge Up

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	2280.2	2283.1	2040.4	2192.7	1969.2	1954.6	1931.6	2183
2	1476	1477.8	1973.7	1965.7	1935.9	1918.8	2125	2112.3
3	1979.9	1974.8	2111.5	2099.8	2357.8	2364.4	2013.2	1990.6
Avg	1912.033333	1911.9	2041.866667	2086.066667	2087.633333	2079.266667	2023.266667	2095.3

Table A-15 Test Case 7—Stack Master Down on CZ-C3750

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	1429.6	1429.9	1740.8	1740.9	1927.3	1927.4	1937.4	1932
2	1650.1	1650.4	1748.6	1759.3	1607.2	1610.6	1646.5	1664.2
3	1139.9	1140.5	1718.8	1719.1	1417.3	1412.6	1346.5	1346.7
Avg	1406.533333	1406.933333	1736.066667	1739.766667	1650.6	1650.2	1643.466667	1647.633333

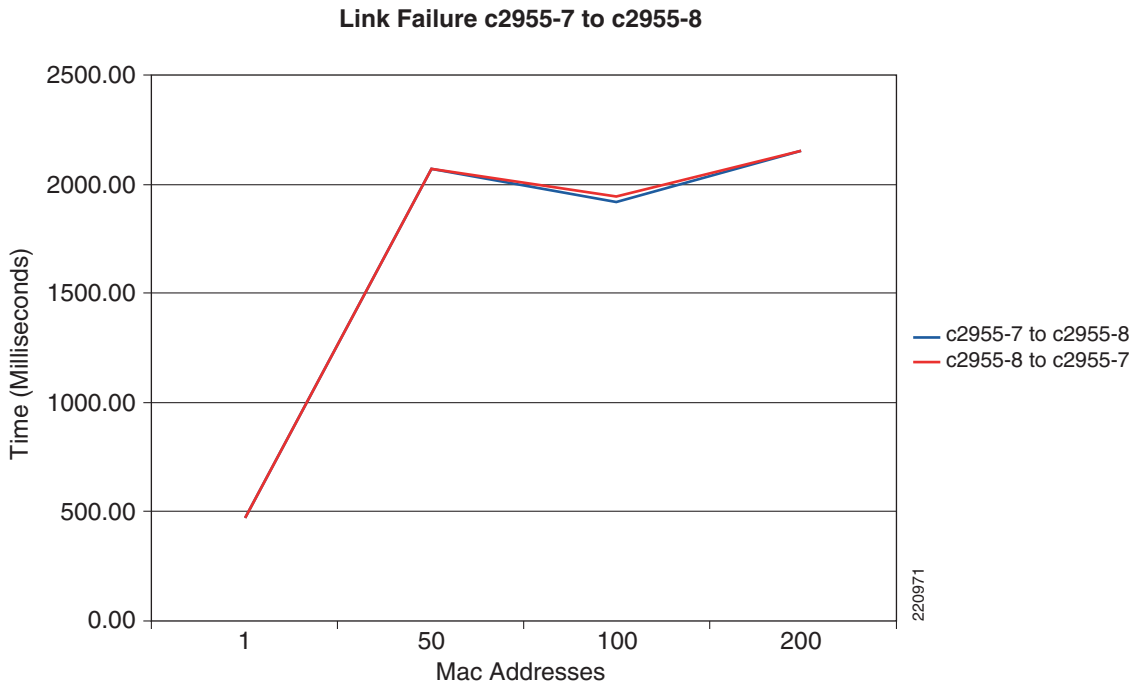
Table A-16 Test Case 8—Stack Master Re-Established on CZ-C3750

Run #	Baseline A to B	Baseline B to A	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	1981.8	1977.2	1948.3	1939.9	1928.4	1923.2	1925.1	1904
2	1978	1983.2	1968.5	1975.6	1935	1935.5	1904.1	1930.5
3	1996.1	1991.6	1952.1	1938.7	1953.2	1926.9	1990.8	1982.7
Avg	1985.3	1984	1956.3	1951.4	1938.866667	1928.533333	1940	1939.066667

Sample Trend Line for Link Failure Between Adjacent Switches

Figure A-6 shows the trend line for link failure between the C2955-7 and C2955-8 switches.

Figure A-6 Link Failure—C2955-7 to C2955-8



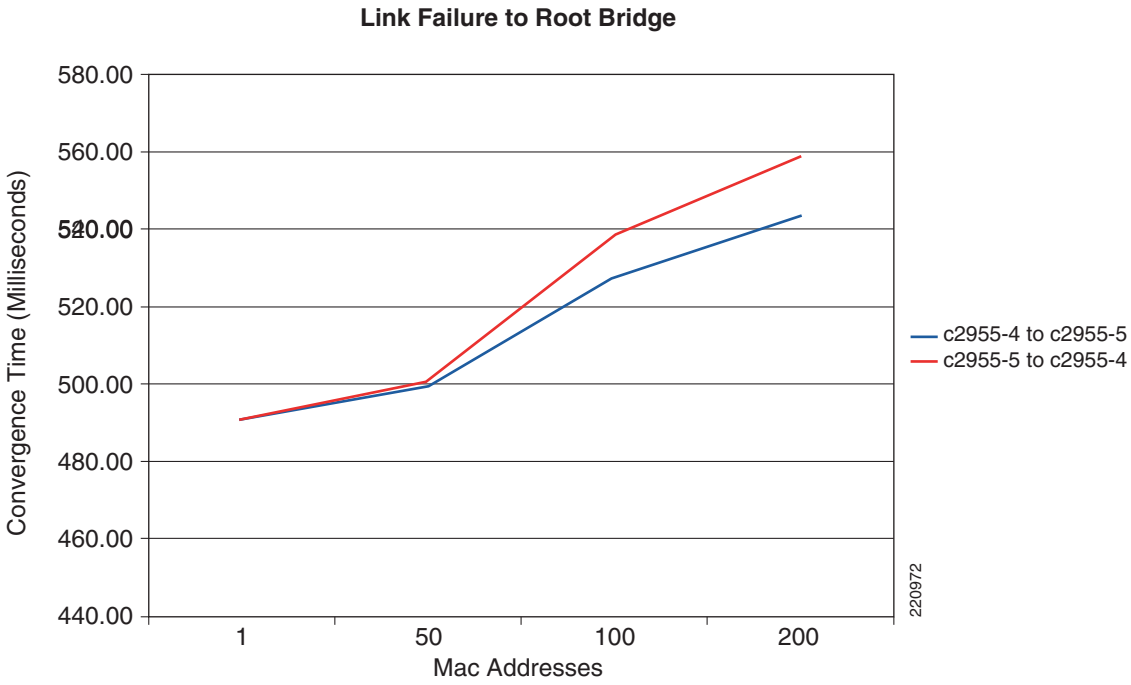
Key findings were as follows:

- ~.5 seconds with one MAC address, and without CIP and producer/consumer traffic
- ~2 seconds with between 50–200 MAC addresses with producer/consumer traffic
- Traffic load (CIP, producer/consumer) increases convergence time
- Number of MAC addresses not a large influence on convergence time

Sample Trend Line for Link Failure To Root Bridge

Figure A-7 shows the trend line for link failure to the root bridge.

Figure A-7 Link Failure to Root Bridge



Key findings were as follows:

- Convergence time is ~490–590 milliseconds, with a slight upward trend depending on number of MAC addresses.

16-Switch Ring—STP Testing

To verify some scaling parameters, testing was performed with double the amount of 2955s in the cell/area zone (16), and a spot check of certain test cases was performed to compare against the 8-switch ring STP tests. The same traffic flow and test methodology exists from the 8-switch tests except that there are more L2 hops from source to destination. Following are the tests and the corresponding results.

Test Suite 1—Bidirectional Traffic from (Tx1 <-> Tx2)

Table A-17 Test Case 1—Physically Remove Link between Cell-C2955-7 and Cell-C2955-8

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	1522.6	1522.5	1907.7	1902	3131.4	3131.4
2	1363.8	1363.7	2299.1	2289.2	2872.7	2858.7
3	1843	1834.4	1934.2	1923	2273.8	2273.7
Avg	1576.466667	1573.533333	2047	2038.066667	2759.3	2754.6

Table A-18 Test Case 2—Physically Reinsert Link between Cell-C2955-7 and Cell-C2955-8

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	954.6	968.9	1993.5	2005.5	1715.4	1743.9
2	1135.2	1149.3	1779.1	1795.2	1987.4	2004.4
3	1993.3	2003.8	1789.5	1805.9	1977.6	2003.2
Avg	1361.033333	1374	1854.033333	1868.866667	1893.466667	1917.166667

Key findings were as follows:

- Very similar results as 8 switch tests
  - Slightly longer convergence times with 200*2 MAC Addresses from ~2.1 seconds to ~2.7 seconds upon link failure
- Other tests not performed because of the similarity of the worst case scenario test from above

Note No baseline measurements were gathered (background traffic was always running).

Test Suite 2—Bidirectional Traffic (Tx3 <-> Tx4)

Table A-19 Test Case 1—Physically Remove Link between Cell-C2955-1 and CZ-C3750

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	585.8	586.2	653.1	645.1	615.7	598.8
2	606	601.1	508.3	500.5	673.8	654.2
3	581.2	576.6	573.6	564.4	648.1	628.4
Avg	591	587.9666667	578.3333333	570	645.8666667	627.1333333

Table A-20 Test Case 2—Physically Reinsert Link between Cell-C2955-1 and CZ-C3750

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	1809.3	1818.7	1758.9	1777.3	1787.5	1775.5
2	1820.8	1872.5	1783.9	1786.3	1707.8	1680.8
3	1817.2	1827.4	1815.4	1824.2	1795	1820.2
Avg	1815.766667	1839.533333	1786.066667	1795.933333	1763.433333	1758.833333

Key findings were as follows:

- Very similar results as 8-switch tests
  - Slightly longer convergence time on link failure test (all MAC addresses), which was expected
- Other tests not performed because of the similarity of the worst-case scenario test from above

Note No baseline measurements were gathered (background traffic was always running).

Redundant Star Topology—STP Testing

Although the majority of the testing was done with the ring topology, the redundant star topology was also tested for comparison purposes. (See Cell/Area Network—Star Topology, page 2-24.) Ixia connections were used between two adjacent 2955 switches. The following test cases were performed.

Table A-21 Test Case 1—Shut Non-Blocking Link on C2955-12

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	24.5	43.9	35.1	61.9	45.5	88.2
2	23.9	50.3	29.8	65.8	44.9	85.2
3	23	46.5	31.8	59.4	47.2	96.5
Avg	23.8	46.9	32.23333333	62.36666667	45.86666667	89.96666667

Table A-22 Test Case 2—Shut Non-Blocking Link on C2955-12

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	1999.7	2015	2017.9	2038.4	1986.8	2016.5
2	2000.5	2012.9	1997.7	2015	1992.6	2017.1
3	1998.8	2015.7	1991.3	2011.9	1994.8	2015.6
Avg	1999.666667	2014.533333	2002.3	2021.766667	1991.4	2016.4

Table A-23 Test Case 3—Physically Remove Non-Blocking Link on C2955-12 (Wire Cut Simulation)

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	555.8	598.6	449.9	478.7	523.5	563.2
2	489.3	510.7	523.5	548.1	479.3	522.8
3	382	404.7	492.7	518.9	509.1	543.6
Avg	475.7	504.6666667	488.7	515.2333333	503.9666667	543.2

Table A-24 Test Case 4—Physically Re-Insert Non-Blocking Link on C2955-12 (Wire Cut Simulation)

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	2000.7	2016.3	1993.5	2013.5	1990.6	2012.9
2	2004	2017.7	1996	2014.8	1992.8	2014
3	1994.9	2011.1	2001.2	2018.2	1993.9	2016.6
Avg	1999.866667	2015.033333	1996.9	2015.5	1992.433333	2014.5

Table A-25 Test Case 5—Fail Root Bridge (Slot 1 on 3750)

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	591	591.3	576	501.9	566.3	520
2	554.3	588.9	584.1	545.4	483.9	570.1
3	562.6	603	532.4	569.1	567	595
Avg	569.3	594.4	564.1666667	538.8	539.0666667	561.7

Table A-26 Test Case 5—Re-establish Root Bridge (Slot 1 on 3750)

Run #	50 MAC A to B	50 MAC B to A	100 MAC A to B	100 MAC B to A	200 MAC A to B	200 MAC B to A
1	131.2	197.7	225.7	240.1	323.3	400.1
2	118.5	193.9	210	308.6	298.2	380
3	123.2	196.7	200.2	337.3	311	281.7
Avg	124.3	196.1	211.9666667	295.3333333	310.8333333	353.9333333

Key findings were as follows:

- Best convergence times compared to ring-8 or ring-16, averaging 500ms consistently
- More consistent numbers
- Worse case for traffic flow is only two L2 hops away

Latency/Jitter Testing

To characterize different network topologies under steady state, latency and jitter measurements were captured. Unlike spanning tree convergence testing, no failures were introduced. These tests assume that the network is functioning normally with typical control device traffic running in the background. Simulated source/destination patterns are worse-case scenarios (in the ring topologies) with traffic traversing the entire ring. This is done by having knowledge of the STP-blocked port before the testing begins.

The following test cases were completed for latency/jitter measurements:

- 8-switch ring—Bidirectional traffic 2955-5 <> 2955-4
- 16-switch ring—Bidirectional traffic 2955-8 <> 2955-9
- Hub/spoke—Bidirectional traffic 2955-12 <> 2955-13

The following results are in microseconds (µ):

Table A-27 Latency/Jitter Test Results

Use Case	Latency Tx3 >Tx4	Jitter Tx3 >Tx4	Latency Tx4 >Tx3	Jitter Tx4 >Tx3
1	43.068	30.94	42.822	33.8
2	65.902	36.92	65.606	36.94
3	27.022	36.34	25.447	34.7

Key findings were as follows:

- Consistent with results from disruptive tests from above
  - Hub/spoke has the best latency, followed by 8-ring and 16-ring.
  - Jitter was consistent across all tests.

IGMP Testing

IGMP Snooping Test Methodology

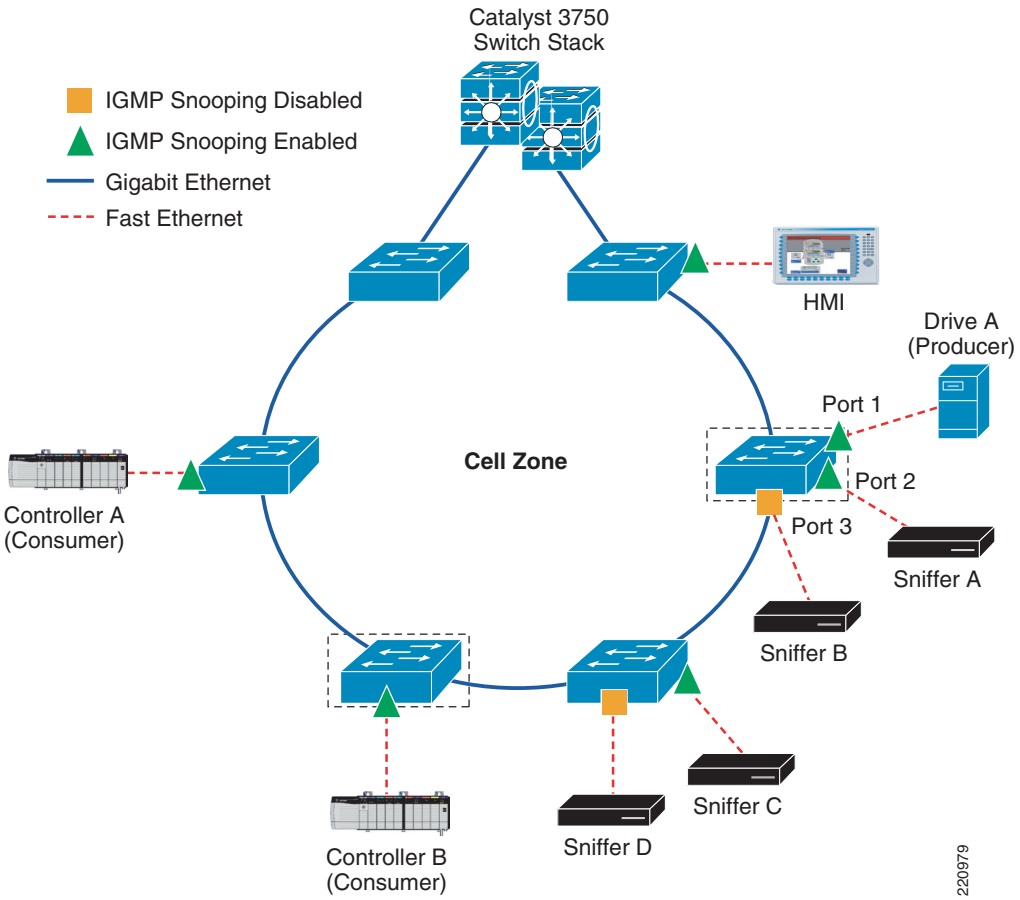
The same eight devices that were used for the STP tests were also used to verify IGMP snooping. The testing exercised various combinations of IGMP snooping with and without a querier on various switches in the network, with active producer-consumer traffic running between PACs and a variable frequency drive. However, as per the Cisco recommended deployment, IGMP snooping works properly only in the presence of a querier. (For more information, see the following URL: http://www.cisco.com/en/US/products/hw/switches/ps708/products_tech_note09186a008059a9df.shtml).

Thus, the only relevant test results are IGMP snooping with querier, and no IGMP snooping with or without querier enabled. A protocol analyzer (http://www.wireshark.org) was used to verify the presence of multicast data traffic.

IGMP Snooping Test Topology

Figure A-8 shows the IGMP snooping test topology.

Figure A-8 IGMP Snooping Test Topology



In this topology, Controller A (Receiver/Consumer) is consuming traffic from Drive A (Producer/Source) across the ring topology. On the same switch that is producing multicast data traffic, a sniffer (Sniffer A) is connected on a different port that has IGMP snooping enabled to verify that this traffic is *not* seen on this port. The same verification is done on another port with IGMP snooping disabled. Finally, the test was repeated on a different switch in the ring with Sniffer C and Sniffer D, respectively.

IGMP Snooping Test Results

Table A-28 shows the IGMP snooping test results. Note the following:

- Yes = Receiving multicast data traffic (destined to 239.x.x.x)
- No = Not receiving multicast data traffic (destined to 239.x.x.x)

Table A-28 IGMP Snooping Test Results

Querier/Snooping Enabled	IGMP Client	Non-IGMP Client Same Switch	Non-IGMP Client Different Switch
OFF/OFF	Yes	Yes	Yes
ON/ON	Yes	No	No