****

ATM Forum/98-0410

****

Title: Proposed modified text for Methodology for Implementing Scalable Test Configurations

****

Abstract: This contribution provides revised text for Appendix B on scalable configurations.

****

Source: Arian Durresi[♦], Raj Jain[♦], Gojko Babic[♦], and Bruce Northcote[♣]

****

Date: Portland, July 26-31, 1998

****

Distribution: ATM Forum Technical Working Group Members (AF-TEST, AF-TM)

****

****

Raj Jain is now at
Washington University in Saint Louis
Jain@cse.wustl.edu
http://www.cse.wustl.edu/~jain/

[♦] The Ohio State University
Department of CIS, Columbus, OH 43210-1277
Phone: 614-292-3989, Fax: 614-292-2911, Email: Jain@ACM.Org
The presentation, by these authors, of this contribution at the ATM Forum is sponsored by NASA.

[♣] Fujitsu Network Communications
289 Great Rd, Acton, MA 01720
Phone: 978-266-4594, Fax: 978-266-2300, Email: bsn@nexen.com

In the April ‘98 ATM Forum meeting at Berlin, it was decided that all text on scalable configurations employing loopbacks should be moved from the normative text of [1] to an informative appendix. That decision is addressed in af98-0452. Also, it was agreed that there existed additional scalable configurations, other than those that employ loopbacks, that may be used to load an IUT without requiring a 1-to-1 correspondence between traffic generators and IUT ports. The purpose of this contribution is to provide a more concise text for the informative appendix on scalable configurations, and we therefore propose a revision of Appendix B in [1]. The new scalable configurations that were discussed in Berlin rely on employing the point-to-multipoint capability of an another switching system (in addition to the IUT). As such, we consider such a configuration to provide a “Parallel Traffic Replication” capability, whereas scalable configurations using loopbacks may be considered to provide a “Serial Traffic Replication” capability. This revision of Appendix B addresses these distinct configuration categories in separate sections.

Appendix B of the current baseline draft [1] contains two different types of scalable configurations with loopbacks. These can be called unidirectional and bi-directional configurations, respectively. The configuration rules presented here in the section on “Serial Traffic Replication” combine the best features of both of these types of configurations and present one set of unified configurations.

Motion: Replace Appendix B by the remaining text of this contribution (other than the references section and footnotes).

Appendix B: Methodology for Implementing Scalable Test Configurations

B.1. Introduction

Throughout this appendix it is assumed, for improved readability, that the IUT consists of a single switch, although the methodologies presented here apply equally to test cases in which the IUT is a network of switches or, alternatively, a subset of modules of a single switch. The notation P_{ij} is used to refer to the j^{th} port of the i^{th} module of the IUT, and (P_{ab}, P_{cd}) indicates that a connection (either internal or external to the IUT) exists between P_{ab} and P_{cd}.

In Sections 4.1.5 and 4.2.6, a number of connection configurations have been presented for throughput and latency measurements. In most of the cases, these configurations require one traffic generator and/or analyzer for each switch port. Thus, the number of generators and/or analyzers increases as the number of ports increases. Since this equipment is rather expensive, it is desirable to define scalable configurations that can be used with a limited number of generators. However, one problem with scalable configurations is that there are many ways to set up the connections and measurement results could vary with the setup. For example, In the case of unicast, it may not be possible to overload a port with only one generator. Using two generators in scalable configurations may exhibit different behavior, such as overloading, that may not show up with one generator.[1]

Performance testing requires two kinds of virtual channel connections (VCCs): foreground VCCs (traffic that is measured) and background VCCs (traffic that simply interferes with the foreground traffic). The methodology for generating configurations of both types of VCCs is covered by this appendix.

The VCCs are formed by setting up connections between ports of the switch. The connections are internal through the switch fabric and external through some transmission medium or wires (which could be cables, fibers, or even wireless links), depending on the port technology. In this Appendix, internal connections are shown by thin lines and external connections by thick lines. An arrow indicates the direction of the connection. If a connection is bi-directional, which is often the case, arrows are not used. It should be noted that whenever external connections are used in the test configurations, only permanent VCCs can be established.[2]

Two generic categories of scalable configuration are presented in this appendix, namely:

1. “Parallel Traffic Replication” configurations, discussed in Section B.2, which employ the point-to-multipoint capability of a switching system (other than the IUT) to artificially generate more traffic than is possible with a limited number of traffic generators, and
2. “Serial Traffic Replication” configurations, discussed in Section B.3, which employ external connections to serially relay traffic egressing from the IUT back in to the IUT, thereby emulating additional traffic generators.

B.2. Parallel Traffic Replication

The point-to-multipoint capability of a switching system is a very powerful method for traffic replication, intended primarily for broadcast communication services, but which also lends itself well to the task of generating the traffic inputs to the IUT that are required for the test configurations shown in Figure 4.2. Identical ATM cells are broadcast in parallel from multiple output ports – hence ‘parallel traffic replication’. Given a single traffic generator, and a switching system (other than the IUT) with a point-to-multipoint capability (a multicast switch), an IUT may receive traffic on as many input ports as the multicast switch has available output ports. This form of scalable configuration is depicted in Figure B.1, where G is the single traffic generator. Internal to the IUT, any of the configurations from Figure 4.2 may be used.

Note that if the multicast switch does not support multipoint-to-point connections, then this form of parallel traffic replication cannot support bi-directional connection configurations. In such cases, it may be necessary to use serial traffic replication, as described in the next section.

[1] This text has been moved from Section 4.1.7 in accordance with Motion 3 of af98-0452
[2] This text has been moved from Section 4.1.7 in accordance with Motion 2 of af98-0452.

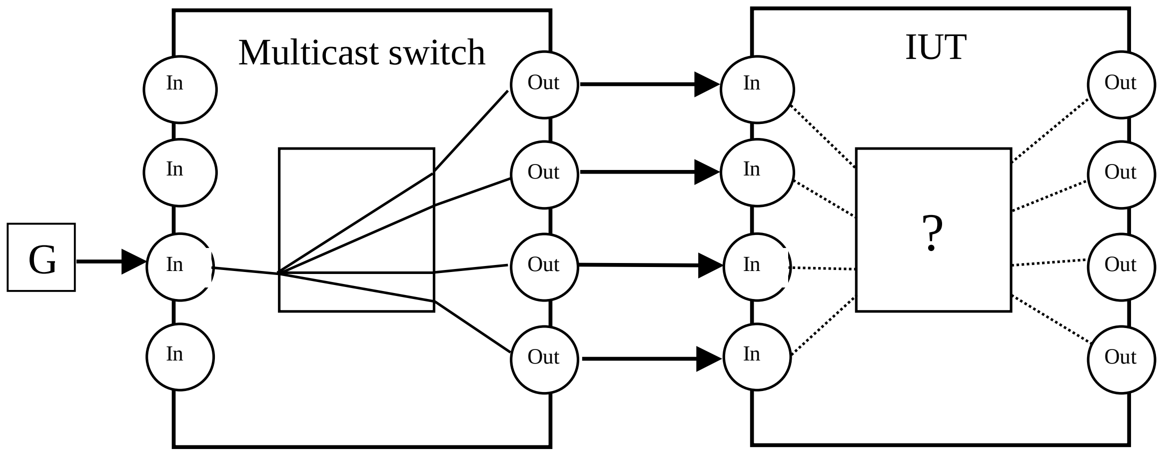


Figure B.1. A parallel traffic replication scalable configuration

B.3. Serial Traffic Replication

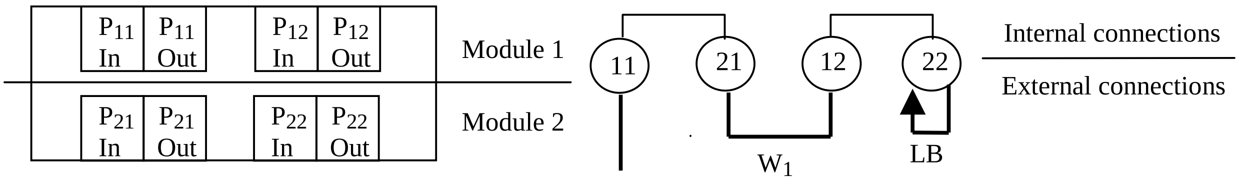
An example test configuration employing serial traffic replication is provided in Figure B.2, which shows a 4-port switch with ports labeled as P_{11}, P_{12}, P_{21} and P_{22}. Of these, ports P_{21} and P_{12} are connected by a wire W_1, while port P_{22} has a "loopback" wire LB that connects the output of the port to its input. Internally, a PVC has been set up to connect ports P_{11} with P_{21} and P_{12} with P_{22}. Note that all external connections (wires) and internal connections (PVCs) in this case are bi-directional, except the loopback. During testing with this configuration, cells first enter the switch at P_{11} and are passed through every port of the switch in series, before looping back at P_{22} and following the reverse path back to exit the switch for the last time at P_{11}.

The methodology presented here has two phases. During the first phase the switch ports are connected externally by numbered wires, as in Section B.3.1. The second phase consists of setting up PVCs, i.e. internal connections between ports, as explained in Section B.3.2.

The sequence of concatenated connections (internal and external) is called a **VCC Chain**. For example, the VCC shown in Figure B.2.b. is formed by setting up a VCC chain starting from P_{11}-In. ATM cells flow internally from P_{11}-In to P_{21}-Out, externally via wire W_1 to P_{12}-In, internally to P_{22}-Out, externally via wire LB to P_{22}-In, internally to P_{12}-Out, externally through wire W_1 to P_{21}-In, finally exiting at P_{11}-Out. This VCC chain can be indicated as:

Generator-P_{11}-P_{21}-P_{12}-P_{22}-P_{22}-P_{12}-P_{21}-P_{11}-Analyzer.

Of these connections, P_{22}-P_{22} is a unidirectional external connection (loopback, denoted as LB) and P_{12}-P_{21} is a bi-directional external connection (wire, denoted as W). All of the internal connections (VCCs) are bi-directional. The sequence of external connections used in this VCC chain is: Generator-W_1-LB-W_1-Analyzer. Both the above notations are symmetric in the sense that the second half of the chain is a mirror image of the first half. For example, W_1-LB is the mirror image of LB-W_1.



a) Representation of physical switch

b) Logical representation of the switch and its port connections.

Figure B.2. A VCC chain that can implement the 4–to-4 straight configuration.

Another possible configuration for this "n-to-n single generator scalable configuration" is P_{11}-P_{12}-P_{21}-P_{22}-P_{22}-P_{21}-P_{12}-P_{11}. The various VCC chains may be distinguished by the order of, and the direction through which, each wire is initially traversed by the generated traffic.

The four-port switch shown in Figure B.2 consists of two modules with two ports each. The measured performance for a given test configuration may depend upon whether the internal connections of the VCC chain are inter-module, intra-module, or a mixture of both. The methodology presented in this appendix ensures that it is possible for exclusively inter-module, or intra-module traffic to be carried.

B.3.1. Implementation of External Connections

The methodology for implementing the external connections consists of the following three steps:

1. Identify the modules to be included in the IUT and label the ports (using P_{ij} format).
2. Connect the generators and analyzers to appropriate ports.
3. Establish and number external connections (wires) to use all the remaining ports of the IUT.

These steps are now explained.

Step 1. Identifying the modules to be included in the IUT

In order to ensure that it is possible for the configuration to support exclusively inter-module and/or intra-module internal connections, the IUT should consist of pairs of similar modules. If this constraint is not satisfied, the VCCs that are established may be a mixture of inter-module and intra-module connections. It is not necessary that the modules/ports be labeled, although we use the P_{ij} format here to assist in the description of the methodology.

Consider a switch with several modules of different port types. The ports could be different in speed and/or connector type. Each module may have a different number of ports. For example, a switch may have two modules of eight and six 155-Mbps single-mode fiber ports, respectively, another module with eight 155-Mpbs UTP ports and a fourth module with six 25-Mbps UTP ports. Figure B.3 shows an example IUT where the modules are grouped by type. The first group consists of two 25-Mbps UTP modules, the second group consists of two 155-Mbps single fiber modules. External connections may only be established between ports that are co-located within the same group (hence the constraint that modules come in pairs for inter-module connectivity).

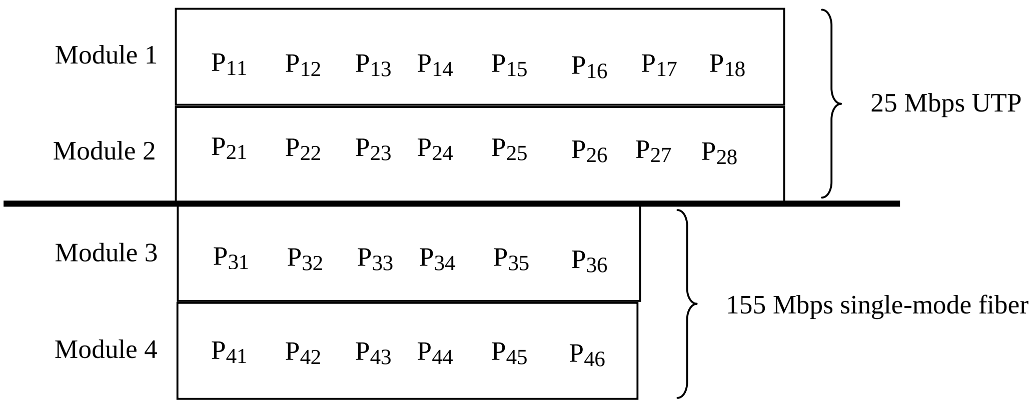


Figure B.3. Example partitioning of modules into groups.

Step 2. Connect the generators and analyzers to appropriate ports

A port must be reserved for each generator/analyzer that is to be used in the test. These reserved ports cannot be used in the next step that establishes external connections. The methodology presented here allows any given number, $r<n$, of generators. Some additional constraints on the number of ports in the IUT are explained in the next step.

Step 3. Establish and number external connections

After selecting the ports that are reserved for connection to generators/analyzers, the remaining ports have to be externally connected with numbered “wires”. The following guidelines should be followed when establishing the wires:

1. Partition the remaining (non-reserved) ports into subgroups, whilst ensuring that there is an odd number of ports in each subgroup.
2. Assign each generator/analyzer to a subgroup. To establish a “straight” connection configuration it is necessary that there exist a 1-to-1 correspondence between subgroups and generators with an even partitioning of ports into subgroups. For other test configurations, such as “full cross” or “partial cross” (see Figure 4.2), more than one generator may be assigned to a subgroup, and the ports need not be evenly distributed between subgroups.
3. With m non-reserved ports in a particular subgroup (m being odd), the first m-1 ports are pair-wise connected by wires, numbered consecutively from 1 across all subgroups. i.e. the 1^{st} subgroup’s wires would be W_1 to W_x, where $x = (m-1)/2$, and the 2^{nd} subgroup would have wires numbered from W_{x+1}. It is preferable that wires be established between ports on different modules to ensure that exclusively inter-module or intra-module traffic may be carried. Wires cannot connect ports of different types.
4. The last (m^{th}) port of each subgroup is occupied by a loopback, labeled as LB_g for the g^{th} subgroup, that will redirect all traffic egressing from the port back to the ingress of the port.

The following example illustrates the methodology for establishing the wires:

Consider the n-to-n straight configuration required for the foreground traffic in throughput measurement. Suppose the switch has two modules with four ports each of the same speed and connection type. The ports are labeled as shown in Figure B.4.a. P_{11} is arbitrarily selected to be connected to the single generator/analyzer that is to be used. There will only be one subgroup, because there is only one generator/analyzer and all the ports are of the same speed and connection type. The non-reserved ports in the subgroup are {P_{12}, P_{13}, P_{14}, P_{21}, P_{22}, P_{23}, P_{24}}. The wires W_1=(P_{12}, P_{21}), W_2=(P_{13}, P_{22}) and W_3=(P_{14}, P_{23}) are obtained by alternatively selecting ports of the first and second module from the non-reserved list of ports. Finally, the loopback is placed at the remaining port, namely P_{24}. Figure B.4.b shows the resulting wiring configuration. Note that it will allow for either exclusively inter-module, or exclusively intra-module traffic (this will be shown in the next section).

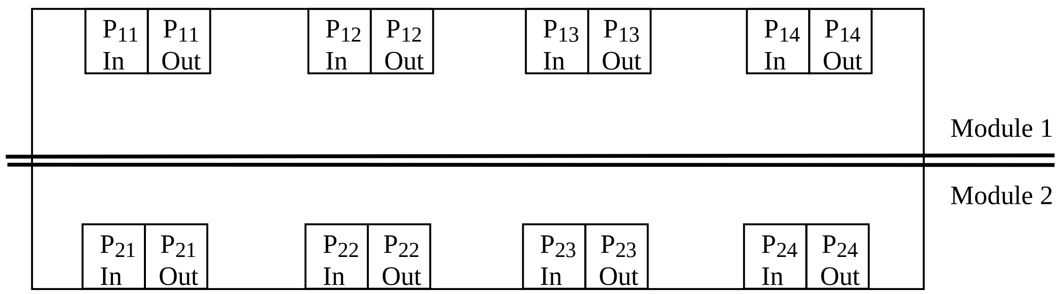


Figure B.4.a. Port labeling of the example switch (2 modules of 4 ports each).

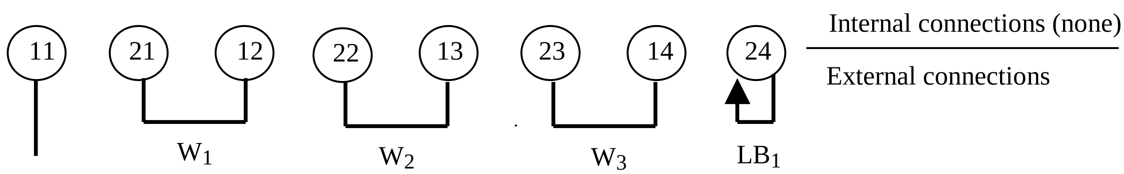


Figure B.4.b. Wiring configuration for the example switch.

B.3.2. Implementation of Internal Connections

The methodology presented in this appendix can ensure that exclusively inter-module or intra-modules traffic is carried, depending on the implementation of the internal connections. For example, Figures B.4.a and B.4.b show configurations for intra-module and inter-module configurations, respectively, although both are based on the wiring indicated in Figure B.4.b.

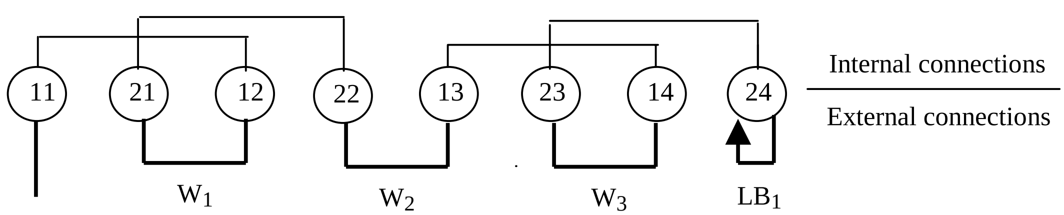


Figure B.5.a. An 8-to-8 straight configuration for the example switch using intra-module VCCs.

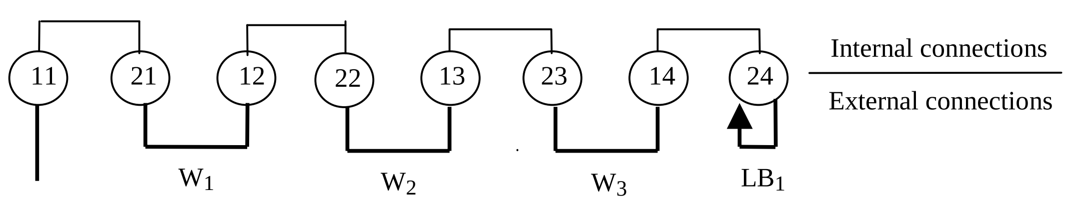


Figure B.5.b. An 8-to-8 straight configuration for the example switch using inter-module VCCs.

As indicated earlier, VCC chains may be distinguished by the order of, and the direction through which, each wire is initially traversed by the generated traffic. We only consider VCC chains that use every non-reserved port within a single subgroup.

Using the same terminology as in Section B.3.1, assume that we have established x wires and a single loopback for a subgroup with m non-reserved ports, and r generators. For a given traffic flow (intra-module or inter-module), a VCC chain that passes through each non-reserved port can be expressed as:

generator – 'x wires in series' – LB – 'x wires in reverse series' – analyzer.

Stated more succinctly, the VCC chain only depends on the generator/analyzer used and the ordering of the 'x wires in series'. The example in Figure B.5 used the ordering $W_1W_2W_3$. For a given traffic generator and wire ordering there exists a unique set of VCCs that provides an intra-module VCC chain. Similarly for an inter-module VCC chain.

Without loss of generality, assume that the wire ordering is $W_1W_2 \ldots W_x$. Let P_g be the port connected to the generator for this VCC chain, and P_{LB} be the port that has the loopback. To complete the construction of the VCC chain, all that remains is to establish the VCCs, as follows:

1. Set $P_{in} = P_g$ and i = 1.
2. Set P_{out} = the port from W_i that is/isn't located on the same module as P_{in} for an intra/inter-module VCC chain, respectively.
3. Establish the bi-directional internal connection $V_i = (P_{in}, P_{out})$.
4. Set P_{in} to be the other port from W_i (not P_{out}).
5. If (i < x), set i = i+1 and return to step 2, otherwise continue.
6. Establish the bi-directional internal connection $V_{x+1} = (P_{in}, P_{LB})$.

The VCC chain is now fully specified as:

generator-V_1-W_1-V_2-W_2- … -W_x-V_{x+1}-LB-V_{x+1}-W_x- … -W_2-V_2-W_1-V_1-analyzer.

Clearly, if any other wire ordering, or any other generator (out of the r generators assigned to the subgroup) was used, a different VCC chain would have resulted.

Referring again to the example provided in Figures B.4.a and B.4.b, only one VCC chain is established for each traffic flow. In the case of an n-to-m partial cross configuration with a single generator, several VCC chains are required, each based on a different ordering of the same subgroup of wires. The six (3!) possible permutations for the example are: $W_1W_2W_3$, $W_2W_3W_1$, $W_3W_1W_2$, $W_3W_2W_1$, $W_2W_1W_3$ and $W_1W_3W_2$, each of which would result in a distinct VCC chain for the single generator.

The examples given in Section B.3.4 illustrate the ways in which multiple VCC chains and/or multiple generators may be used in serial traffic replication scalable configurations.

B.3.3. Background Traffic

To establish a configuration that incorporates background test traffic, the background traffic may:

1) ingress and egress on ports distinct from those used by the foreground traffic,

2) ingress with, but egress at a port distinct from, the foreground traffic, or

3) ingress at a port distinct from, but egress with, the foreground traffic.

To implement a configuration with background traffic, one or more ports need to be reserved for foreground traffic. Therefore, to implement:

Case 1 (distinct ingress and egress) – reserve 2 ports for each foreground traffic stream.

Cases 2 & 3 (shared ingress or egress) – reserve 1 port per foreground traffic stream.

B.3.4. Examples of scalable connection configurations

In this section, several examples of scalable connection configurations are provided. In all of the examples, a switch with two 4-port modules is used (as in Figure B.4.a), where all ports are of the same speed and connector type.

B.3.4.1. n-to-n Straight (Single Generator)

This configuration may be used for throughput as well as latency measurements. Suitable test configurations that employ serial traffic replication can be obtained as follows:

a) Foreground traffic (Throughput measurements)

For these tests, only a single chain starting from a single generator is needed. Figures B.4.a and B.4.b, provide adequate examples of this type of connection configuration.

b) Background traffic (Latency Measurements)

In this example, the background traffic does not use the input/output ports of the foreground traffic. As shown in Figure B.6, generator/analyzer G_1 is used for background traffic while generator/analyzer G_2 is used for foreground traffic.

The background traffic passes through each port not assigned to the foreground traffic. Inter-module external connections are established by following the guidelines described in Section B.3.1, resulting in wires W_1, W_2, and LB_1. The VCC chain of the background traffic corresponds to the wire ordering W_1W_2. So the VCC chain is given by :

$$G_1\text{-}V_1\text{-}W_1\text{-}V_2\text{-}W_2\text{-}V_3\text{-}LB_1\text{-}V_3\text{-}W_2\text{-}V_2\text{-}W_1\text{-}V_1\text{-}G_1, \text{ where,}$$

by establishing exclusively inter-module VCCs: $V_1 = (P_{12}, P_{22})$, $V_2 = (P_{13}, P_{23})$, $V_3 = (P_{14}, P_{24})$.

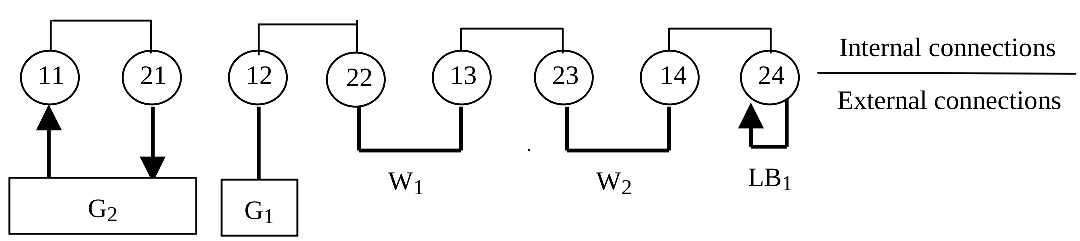


Figure B.6. The 6-to-6 straight configuration with one generator using inter-module VCCs, where the foreground traffic does not share any port with the background traffic.

B.3.4.2. n-to-n Straight (r Generators)

Foreground traffic
To realize an n-to-n straight configuration with r generators, we need to design r VCC chains. Of the n ports, r ports are used as the source/destination of these chains. The remaining ports are connected among themselves and their wires are divided in subgroups among the generators ensuring an odd number of ports in each subgroup.

As an example, consider the 8-port switch again, with r = 3 generators. In dividing the available ports in three subgroups the goal is to have an odd number of ports in each subgroup. The partitioning of ports into subgroups results in one subgroup with three ports and two with one port each. The three ports subgroup is used by the first generator. Note that the wiring configurations of the other two subgroups consist only of a single loopback. Figure B.7 illustrates the implementation of the VCC chains for this case. First we select the source and destination ports. Let, P_{11} be the input/output port for the first chain, P_{21} be the input/output port for the second chain, and P_{12} be the input/output port for the third chain. Using only intra-module VCCs the following VCC chains are obtained:

$$G_1\text{-}V_1\text{-}W_1\text{-}LB_1\text{-}W_1\text{-}V_1\text{-}G_1,$$
$$G_2\text{-}V_2\text{-}LB_2\text{-}V_2\text{-}G_2, \text{ and}$$
$$G_3\text{-}V_3\text{-}LB_3\text{-}V_3\text{-}G_3, \text{ where}$$
$$V_1 = (P_{11}, P_{13}),\ V_2 = (P_{21}, P_{24}) \text{ and } V_3 = (P_{12}, P_{14}).$$

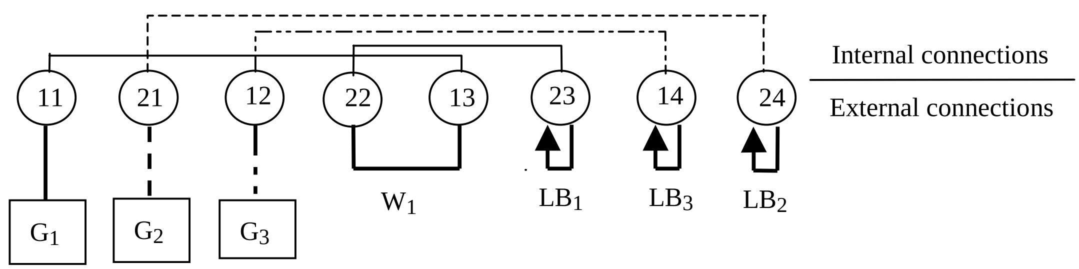


Figure B.7. Implementation of the 8-to-8 straight configuration with 3 generators using intra-module VCCs.

B.3.4.3. n-to-m Partial Cross (r Generators)

This configuration has m*r VCC chains starting from r generators**,** where each generator originates m VCC chains. Each chain has a load of 1/mth of the traffic egressing from the generator. Each intermediate wire has exactly m of these streams flowing through it. There are r subgroups and the switch ports, other than those reserved to be connected to the r generators, are divided among them.

a) Foreground traffic: 8-to-2 (m=2) partial cross configuration with 2 generators (r=2).

For the configuration example shown in Figure B.8, there are two subgroups (one for each generator) with three ports each. The following intra-module VCC chains form the required test configuration:

G_1-V_1-W_1-V_2-LB_1-V_2-W_1-V_1-G_1,
G_2-V_3-W_2-V_4-LB_2-V_4-W_2-V_3-G_2,
G_1-V_5-W_1-V_6-LB_1-V_6-W_1-V_5-G_1, and
G_2-V_7-W_2-V_8-LB_2-V_8-W_2-V_7-G_2, where
$V_1 = (P_{11}, P_{13})$, $V_2 = (P_{21}, P_{23})$, $V_3 = (P_{12}, P_{14})$, $V_4 = (P_{22}, P_{24})$, $V_5 = (P_{11}, P_{14})$, $V_6 = (P_{22}, P_{24})$,
$V_7 = (P_{12}, P_{13})$, and $V_8 = (P_{21}, P_{23})$.

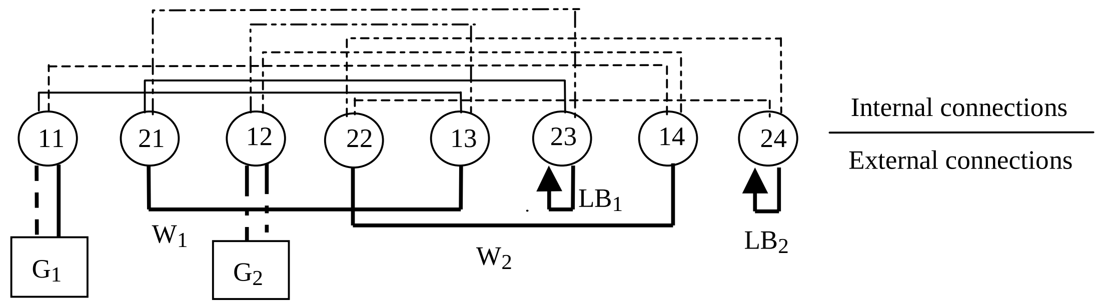


Figure B.8. Implementation of 8-to-2 partial cross configuration with 2 generators for foreground traffic using intra-module VCCs.

b) Foreground traffic: 8-to-3 partial cross with one generator

This case is illustrated in Figure B.9. There is only one subgroup composed of wires W1, W2, W3. The three VCC chains required for this test configuration (each constructed from a distinct wire ordering, with inter-module VCCs) are:

generator-V_1-W_1-V_2-W_2-V_3-W_3-V_4-LB_1-V_4-W_3-V_3-W_2-V_2-W_1-V_1-analyzer,
generator-V_5-W_2-V_6-W_3-V_7-W_1-V_8-LB_1-V_8-W_1-V_7-W_3-V_6-W_2-V_5-analyzer, and
generator-V_9-W_3-V_{10}-W_1-V_{11}-W_2-V_{12}-LB_1-V_{12}-W_2-V_{11}-W_1-V_{10}-W_3-V_9-analyzer,
where for tests involving exclusively inter-module traffic, the VCCs are:
$V_1 = (P_{11}, P_{21})$, $V_2 = (P_{12}, P_{22})$, $V_3 = (P_{13}, P_{23})$, $V_4 = (P_{14}, P_{24})$, $V_5 = (P_{11}, P_{22})$, $V_6 = (P_{13}, P_{23})$,
$V_7 = (P_{14}, P_{21})$, $V_8 = (P_{12}, P_{24})$, $V_9 = (P_{11}, P_{23})$, $V_{10} = (P_{14}, P_{21})$, $V_{11} = (P_{12}, P_{22})$, $V_{12} = (P_{13}, P_{24})$.

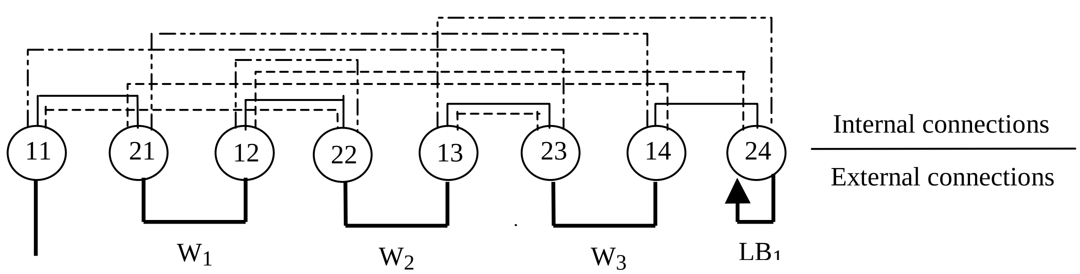


Figure B.9. 8-to-3 partial cross with one generator using inter-module VCCs

References:

1. ATM Forum/BTD-TEST-TM-PERF.00.07 (Draft)