

Methodology for ATM Benchmarking

Status of this Memo

This memo provides information for the Internet community. It does not specify an Internet standard of any kind. Distribution of this memo is unlimited.

Copyright Notice

Copyright (C) The Internet Society (2001). All Rights Reserved.

Abstract

This document discusses and defines a number of tests that may be used to describe the performance characteristics of ATM (Asynchronous Transfer Mode) based switching devices. In addition to defining the tests this document also describes specific formats for reporting the results of the tests.

This memo is a product of the Benchmarking Methodology Working Group (BMWG) of the Internet Engineering Task Force (IETF).

Table of Contents

1. Introduction	4
2. Background	5
2.1. Test Device Requirements	5
2.2. Systems Under Test (SUTs).	5
2.3. Test Result Evaluation	5
2.4. Requirements	5
2.5. Test Configurations for SONET.	6
2.6. SUT Configuration.	7
2.7. Frame Formats.	8
2.8. Frame Sizes.	8
2.9. Verifying Received IP PDU's.	9
2.10. Modifiers	9
2.10.1. Management IP PDU's	9
2.10.2. Routing Update IP PDU's	10
2.11. Filters	10
2.11.1. Filter Addresses.	11
2.12. Protocol Addresses.	12

2.13. Route Set Up.	12
2.14. Bidirectional Traffic	12
2.15. Single Stream Path.	12
2.16. Multi-port.	13
2.17. Multiple Protocols.	14
2.18. Multiple IP PDU Sizes	14
2.19. Testing Beyond a Single SUT	14
2.20. Maximum IP PDU Rate	15
2.21. Busty Traffic	15
2.22. Trial Description	16
2.23. Trial Duration.	16
2.24. Address Resolution.	16
2.25. Synchronized Payload Bit Pattern.	16
2.26. Burst Traffic Descriptors	17
3. Performance Metrics.	17
3.1. Physical Layer-SONET	17
3.1.1. Pointer Movements.	17
3.1.1.1. Pointer Movement Propagation	17
3.1.1.2. Cell Loss due to Pointer Movement.	19
3.1.1.3. IP Packet Loss due to Pointer Movement	20
3.1.2. Transport Overhead (TOH) Error Count	21
3.1.2.1. TOH Error Propagation.	21
3.1.2.2. Cell Loss due to TOH Error	22
3.1.2.3. IP Packet Loss due to TOH Error.	23
3.1.3. Path Overhead (POH) Error Count.	24
3.1.3.1. POH Error Propagation.	24
3.1.3.2. Cell Loss due to POH Error	25
3.1.3.3. IP Packet Loss due to POH Error.	26
3.2. ATM Layer.	27
3.2.1. Two-Point Cell Delay Variation (CDV)	27
3.2.1.1. Test Setup	27
3.2.1.2. Two-point CDV/Steady Load/One VCC.	27
3.2.1.3. Two-point CDV/Steady Load/Twelve VCCs.	28
3.2.1.4. Two-point CDV/Steady Load/Maximum VCCs	30
3.2.1.5. Two-point CDV/Bursty VBR Load/One VCC.	31
3.2.1.6. Two-point CDV/Bursty VBR Load/Twelve VCCs.	32
3.2.1.7. Two-point CDV/Bursty VBR Load/Maximum VCCs	34
3.2.1.8. Two-point CDV/Mixed Load/Three VCC's	35
3.2.1.9. Two-point CDV/Mixed Load/Twelve VCCs	36
3.2.1.10. Two-point CDV/Mixed Load/Maximum VCCs	38
3.2.2. Cell Error Ratio (CER)	39
3.2.2.1. Test Setup	39
3.2.2.2. CER/Steady Load/One VCC.	40
3.2.2.3. CER/Steady Load/Twelve VCCs.	41
3.2.2.4. CER/Steady Load/Maximum VCCs	42
3.2.2.5. CER/Bursty VBR Load/One VCC.	43
3.2.2.6. CER/Bursty VBR Load/Twelve VCCs.	44
3.2.2.7. CER/Bursty VBR Load/Maximum VCCs	46

3.2.3. Cell Loss Ratio (CLR)	47
3.2.3.1. CLR/Steady Load/One VCC	47
3.2.3.2. CLR/Steady Load/Twelve VCCs	48
3.2.3.3. CLR/Steady Load/Maximum VCCs	49
3.2.3.4. CLR/Bursty VBR Load/One VCC	51
3.2.3.5. CLR/Bursty VBR Load/Twelve VCCs	52
3.2.3.6. CLR/Bursty VBR Load/Maximum VCCs	53
3.2.4. Cell Misinsertion Rate (CMR)	54
3.2.4.1. CMR/Steady Load/One VCC	54
3.2.4.2. CMR/Steady Load/Twelve VCCs	55
3.2.4.3. CMR/Steady Load/Maximum VCCs	57
3.2.4.4. CMR/Bursty VBR Load/One VCC	58
3.2.4.5. CMR/Bursty VBR Load/Twelve VCCs	59
3.2.4.6. CMR/Bursty VBR Load/Maximum VCCs	60
3.2.5. CRC Error Ratio (CRC-ER)	62
3.2.5.1. CRC-ER/Steady Load/One VCC	62
3.2.5.2. CRC-ER/Steady Load/Twelve VCCs	63
3.2.5.3. CRC-ER/Steady Load/Maximum VCCs	64
3.2.5.4. CRC-ER/Bursty VBR Load/One VCC	65
3.2.5.5. CRC-ER/Bursty VBR Load/Twelve VCCs	66
3.2.5.6. CRC-ER/Bursty VBR Load/Maximum VCCs	68
3.2.5.7. CRC-ER/Bursty UBR Load/One VCC	69
3.2.5.8. CRC-ER/Bursty UBR Load/Twelve VCCs	70
3.2.5.9. CRC-ER/Bursty UBR Load/Maximum VCCs	71
3.2.5.10. CRC-ER/Bursty Mixed Load/Three VCC	73
3.2.5.11. CRC-ER/Bursty Mixed Load/Twelve VCCs	74
3.2.5.12. CRC-ER/Bursty Mixed Load/Maximum VCCs	75
3.2.6. Cell Transfer Delay (CTD)	76
3.2.6.1. Test Setup	76
3.2.6.2. CTD/Steady Load/One VCC	77
3.2.6.3. CTD/Steady Load/Twelve VCCs	78
3.2.6.4. CTD/Steady Load/Maximum VCCs	79
3.2.6.5. CTD/Bursty VBR Load/One VCC	81
3.2.6.6. CTD/Bursty VBR Load/Twelve VCCs	82
3.2.6.7. CTD/Bursty VBR Load/Maximum VCCs	83
3.2.6.8. CTD/Bursty UBR Load/One VCC	85
3.2.6.9. CTD/Bursty UBR Load/Twelve VCCs	86
3.2.6.10. CTD/Bursty UBR Load/Maximum VCCs	87
3.2.6.11. CTD/Mixed Load/Three VCC's	88
3.2.6.12. CTD/Mixed Load/Twelve VCCs	90
3.2.6.13. CTD/Mixed Load/Maximum VCCs	91
3.3. ATM Adaptation Layer (AAL) Type 5 (AAL5)	93
3.3.1. IP Packet Loss due to AAL5 Re-assembly Errors	93
3.3.2. AAL5 Re-assembly Time	94
3.3.3. AAL5 CRC Error Ratio	95
3.3.3.1. Test Setup	95
3.3.3.2. AAL5-CRC-ER/Steady Load/One VCC	95
3.3.3.3. AAL5-CRC-ER/Steady Load/Twelve VCCs	96

3.3.3.4. AAL5-CRC-ER/Steady Load/Maximum VCCs	97
3.3.3.5. AAL5-CRC-ER/Bursty VBR Load/One VCC.	99
3.3.3.6. AAL5-CRC-ER/Bursty VBR Load/Twelve VCCs.	100
3.3.3.7. AAL5-CRC-ER/Bursty VBR Load/Maximum VCCs	101
3.3.3.8. AAL5-CRC-ER/Mixed Load/Three VCC's	102
3.3.3.9. AAL5-CRC-ER/Mixed Load/Twelve VCCs	104
3.3.3.10. AAL5-CRC-ER/Mixed Load/Maximum VCCs	105
3.4. ATM Service: Signaling	106
3.4.1. CAC Denial Time and Connection Establishment Time.	106
3.4.2. Connection Teardown Time	107
3.4.3. Crankback Time	108
3.4.4. Route Update Response Time	109
3.5. ATM Service: ILMI.	110
3.5.1. MIB Alignment Time	110
3.5.2. Address Registration Time.	111
4. Security Considerations	112
5. Notices.	112
6. References	113
7. Authors' Addresses	113
APPENDIX A	114
APPENDIX B	114
APPENDIX C	116
Full Copyright Statement	127

1. Introduction

This document defines a specific set of tests that vendors can use to measure and report the performance characteristics of ATM network devices. The results of these tests will provide the user comparable data from different vendors with which to evaluate these devices. The methods defined in this memo are based on RFC 2544 "Benchmarking Methodology for Network Interconnect Devices".

The document "Terminology for ATM Benchmarking" (RFC 2761), defines many of the terms that are used in this document. The terminology document should be consulted before attempting to make use of this document.

The BMWG produces two major classes of documents: Benchmarking Terminology documents and Benchmarking Methodology documents. The Terminology documents present the benchmarks and other related terms. The Methodology documents define the procedures required to collect the benchmarks cited in the corresponding Terminology documents.

2. Background

2.1. Test Device Requirements

This document is based on the requirement that a test device is available. The test device can either be off the shelf or can be easily built with current technologies. The test device must have a transmitting and receiving port for the interface type under test. The test device must be configured to transmit test PDUs and to analyze received PDUs. The test device should be able to transmit and analyze received data at the same time.

2.2. Systems Under Test (SUTs)

There are a number of tests described in this document that do not apply to each SUT. Vendors should perform all of the tests that can be supported by a specific product type. It will take some time to perform all of the recommended tests under all of the recommended conditions.

2.3. Test Result Evaluation

Performing all of the tests in this document will result in a great deal of data. The applicability of this data to the evaluation of a particular SUT will depend on its expected use and the configuration of the network in which it will be used. For example, the time required by a switch to provide ILMI services will not be a pertinent measurement in a network that does not use the ILMI protocol, such as an ATM WAN. Evaluating data relevant to a particular network installation may require considerable experience, which may not be readily available. Finally, test selection and evaluation of test results must be done with an understanding of generally accepted testing practices regarding repeatability, variance and the statistical significance of a small numbers of trials.

2.4. Requirements

In this document, the words that are used to define the significance of each particular requirement are capitalized. These words are:

- * "MUST" This word, or the words "REQUIRED" and "SHALL" mean that the item is an absolute requirement of the specification.
- * "SHOULD" This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.

- * "MAY" This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

An implementation is not compliant if it fails to satisfy one or more of the MUST requirements for the protocols it implements. An implementation that satisfies all the MUST and all the SHOULD requirements for its protocols is said to be "unconditionally compliant"; one that satisfies all the MUST requirements but not all the SHOULD requirements for its protocols is said to be "conditionally compliant".

2.5. Test Configurations for SONET

The test device can be connected to the SUT in a variety of configurations depending on the test point. The following configurations will be used for the tests described in this document.

- 1) Uni-directional connection: The test devices transmit port (labeled Tx) is connected to the SUT receive port (labeled Rx). The SUTs transmit port is connected to the test device receive port (see Figure 1). In this configuration, the test device can verify that all transmitted packets are acknowledged correctly. Note that this configuration does not verify internal system functions, but verifies one port on the SUT.

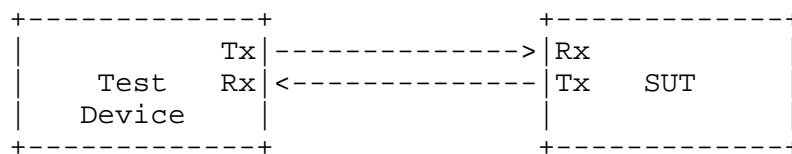


Figure 1

- 2) Bi-directional connection: The test devices first transmit port is connected to the SUTs first receive port. The SUTs first transmit port is connected to the test devices first receive port. The test devices second transmit port is connected to the SUTs second receive port. The SUTs second transmit port is connected to the test devices second receive port (see Figure 2). In this configuration, the test device can determine if all of the transmitted packets were received and forwarded correctly. Note that this configuration does verify internal system functions, since it verifies two ports on the SUT.

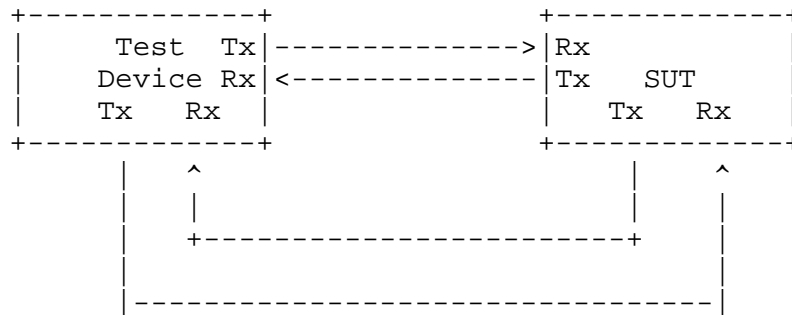


Figure 2

- 3) Uni-directional passthrough connection: The test devices first transmit port is connected to the SUT1 receive port. The SUT1 transmit port is connected to the test devices first receive port. The test devices second transmit port is connected to the SUT2 receive port. The SUT2 transmit port is connected to the test devices second receive port (see Figure 3). In this configuration, the test device can determine if all of the packets transmitted by SUT1 were correctly acknowledged by SUT2. Note that this configuration does not verify internal system functions, but verifies one port on each SUT.

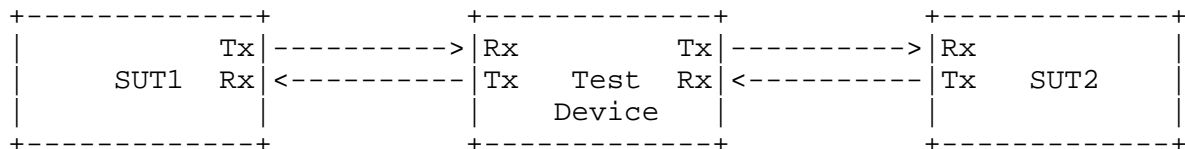


Figure 3

2.6. SUT Configuration

The SUT MUST be configured as described in the SUT users guide. Specifically, it is expected that all of the supported protocols will be configured and enabled. It is expected that all of the tests will be run without changing the configuration or setup of the SUT in any way other than that required to do the specific test. For example, it is not acceptable to disable all but one transport protocol when testing the throughput of that protocol. If PNNI or BISUP is used to initiate switched virtual connections (SVCs), the SUT configuration SHOULD include the normally recommended routing update intervals and keep alive frequency. The specific version of the software and the exact SUT configuration, including what functions are disabled and used during the tests MUST be included as part of the report of the results.

2.7. Frame formats

The formats of the test IP PDUs to use for TCP/IP and UPC/IP over ATM are shown in Appendix C: Test Frame Formats. Note that these IP PDUs are in accordance with RFC 2225. These exact IP PDU formats SHOULD be used in the tests described in this document for this protocol/media combination. These IP PDUs will be used as a template for testing other protocol/media combinations. The specific formats that are used to define the test IP PDUs for a particular test series MUST be included in the report of the results.

2.8. Frame sizes

All of the described tests SHOULD be performed using a number of IP PDU sizes. Specifically, the sizes SHOULD include the maximum and minimum legitimate sizes for the protocol under test on the media under test and enough sizes in between to be able to get a full characterization of the SUT performance. Except where noted, at least five IP PDU sizes SHOULD be tested for each test condition.

Theoretically the minimum size UDP Echo request IP PDU would consist of an IP header (minimum length 20 octets), a UDP header (8 octets), AAL5 trailer (8 octets) and an LLC/SNAP code point header (8 octets); therefore, the minimum size PDU will fit into one ATM cell. The theoretical maximum IP PDU size is determined by the size of the length field in the IP header. In almost all cases the actual maximum and minimum sizes are determined by the limitations of the media. In the case of ATM, the maximum IP PDU size SHOULD be the ATM MTU size, which is 9180 octets.

In theory it would be ideal to distribute the IP PDU sizes in a way that would evenly distribute the theoretical IP PDU rates. These recommendations incorporate this theory but specify IP PDU sizes, which are easy to understand and remember. In addition, many of the same IP PDU sizes are specified on each of the media types to allow for easy performance comparisons.

Note: The inclusion of an unrealistically small IP PDU size on some of the media types (i.e., with little or no space for data) is to help characterize the per-IP PDU processing overhead of the SUT.

The IP PDU sizes that will be used are:

44, 64, 128, 256, 1024, 1518, 2048, 4472, 9180

The minimum size IP PDU for UDP on ATM is 44 octets, the minimum size of 44 is recommended to allow direct comparison to token ring performance. The IP PDU size of 4472 is recommended instead of the

theoretical FDDI maximum size of 4500 octets in order to permit the same type of comparison. An IP (i.e., not UDP) IP PDU may be used in addition if a higher data rate is desired, in which case the minimum IP PDU size is 28 octets.

2.9. Verifying received IP PDUs

The test equipment SHOULD discard any IP PDUs received during a test run that are not actual forwarded test IP PDUs. For example, keep-alive and routing update IP PDUs SHOULD NOT be included in the count of received IP PDUs. In any case, the test equipment SHOULD verify the length of the received IP PDUs and check that they match the expected length.

Preferably, the test equipment SHOULD include sequence numbers in the transmitted IP PDUs and check for these numbers on the received IP PDUs. If this is done, the reported results SHOULD include, in addition to the number of IP PDUs dropped, the number of IP PDUs that were received out of order, the number of duplicate IP PDUs received and the number of gaps in the received IP PDU numbering sequence. This functionality is required for some of the described tests.

2.10. Modifiers

It is useful to characterize the SUTs performance under a number of conditions. Some of these conditions are noted below. The reported results SHOULD include as many of these conditions as the test equipment is able to generate. The suite of tests SHOULD be run first without any modifying conditions, then repeated under each of the modifying conditions separately. To preserve the ability to compare the results of these tests, any IP PDUs that are required to generate the modifying conditions (excluding management queries) will be included in the same data stream as that of the normal test IP PDUs and in place of one of the test IP PDUs. They MUST not be supplied to the SUT on a separate network port.

2.10.1. Management IP PDUs

Most ATM data networks now make use of ILMI, signaling and OAM. In many environments, there can be a number of management stations sending queries to the same SUT at the same time.

Management queries MUST be made in accordance with the applicable specification, e.g., ILMI sysUpTime getNext requests will be made in accordance with ILMI 4.0. The response to the query MUST be verified by the test equipment. Note that, for each management protocol in

use, this requires that the test equipment implement the associated protocol state machine. One example of the specific query IP PDU (ICMP) that should be used is shown in Appendix C.

2.10.2. Routing update IP PDUs

The processing of PNNI updates could have a significant impact on the ability of a switch to forward cells and complete calls. If PNNI is configured on the SUT, one routing update MUST be transmitted before the first test IP PDU is transmitted during the trial. The test SHOULD verify that the SUT has properly processed the routing update.

PNNI routing update IP PDUs SHOULD be sent at the rate specified in Appendix B. Appendix C defines one routing update PDU for the TCP/IP over ATM example. The routing updates are designed to change the routing on a number of networks that are not involved in the forwarding of the test data. The first IP PDU sets the routing table state to "A", the second one changes the state to "B". The IP PDUs MUST be alternated during the trial. The test SHOULD verify that the SUT has properly processed the routing update.

2.11. Filters

Filters are added to switches to selectively inhibit the forwarding of cells that would normally be forwarded. This is usually done to implement security controls on the data that is accepted between one area and another. Different products have different capabilities to implement filters. Filters are applicable only if the SUT supports the filtering feature.

The SUT SHOULD be first configured to add one filter condition and the tests performed. This filter SHOULD permit the forwarding of the test data stream. This filter SHOULD be of the form as described in the SUT Users Guide.

The SUT SHOULD be then reconfigured to implement a total of 25 filters. The first 24 of these filters SHOULD be based on 24 separate ATM NSAP Network Prefix addresses.

The 24 ATM NSAP Network Prefix addresses SHOULD not be any that are represented in the test data stream. The last filter SHOULD permit the forwarding of the test data stream. By "first" and "last" we mean to ensure that in the second case, 25 conditions must be checked before the data IP over ATM PDUs will match the conditions that permit the forwarding of the IP PDU. Of course, if the SUT reorders the filters or does not use a linear scan of the filter rules the effect of the sequence in which the filters are input is properly lost.

The exact filters configuration command lines used SHOULD be included with the report of the results.

2.11.1. Filter Addresses

Two sets of filter addresses are required, one for the single filter case and one for the 25 filter case.

The single filter case should permit traffic from ATM address [Switch Network Prefix] 00 00 00 00 00 01 00 to ATM address [Switch Network Prefix] 00 00 00 00 00 02 00 and deny all other traffic. Note that the 13 octet Switch Network Prefix MUST be configured before this test can be run.

The 25 filter case should follow the following sequence.

```
deny [Switch Network Prefix] 00 00 00 00 00 01 00
to [Switch Network Prefix] 00 00 00 00 00 03 00
deny [Switch Network Prefix] 00 00 00 00 00 01 00
to [Switch Network Prefix] 00 00 00 00 00 04 00
deny [Switch Network Prefix] 00 00 00 00 00 01 00
to [Switch Network Prefix] 00 00 00 00 00 05 00
...
deny [Switch Network Prefix] 00 00 00 00 00 01 00
to [Switch Network Prefix] 00 00 00 00 00 0C 00
deny [Switch Network Prefix] 00 00 00 00 00 01 00
to [Switch Network Prefix] 00 00 00 00 00 0D 00
allow [Switch Network Prefix] 00 00 00 00 00 01 00
to [Switch Network Prefix] 00 00 00 00 00 02 00
deny [Switch Network Prefix] 00 00 00 00 00 01 00
to [Switch Network Prefix] 00 00 00 00 00 0E 00
deny [Switch Network Prefix] 00 00 00 00 00 01 00
to [Switch Network Prefix] 00 00 00 00 00 0F 00
...
deny [Switch Network Prefix] 00 00 00 00 00 01 00
to [Switch Network Prefix] 00 00 00 00 00 18 00
deny all else
```

All previous filter conditions should be cleared from the switch before this sequence is entered. The sequence is selected to test to see if the switch sorts the filter conditions or accepts them in the order that they were entered. Both of these procedures will result in a greater impact on performance than will some form of hash coding.

2.12. Protocol addresses

It is easier to implement these tests using a single logical stream of data, with one source ATM address and one destination ATM address, and for some conditions like the filters described above, a practical requirement. Networks in the real world are not limited to single streams of data. The test suite SHOULD be first run with a single ATM source and destination address pair. The tests SHOULD then be repeated with using a random destination address. In the case of testing single switches, the addresses SHOULD be random and uniformly distributed over a range of 256 seven octet user parts. In the case of testing multiple interconnected switches, the addresses SHOULD be random and uniformly distributed over the 256 network prefixes, each of which should support 256 seven octet user parts. The specific address ranges to use for ATM are shown in Appendix A. IP to ATM address mapping MUST be accomplished as described in RFC 2225.

2.13. Route Set Up

It is not reasonable that all of the routing information necessary to forward the test stream, especially in the multiple address case, will be manually set up. If PNNI and/or ILMI are running, at the start of each trial a routing update MUST be sent to the SUT. This routing update MUST include all of the ATM addresses that will be required for the trial. This routing update will have to be repeated at the interval required by PNNI or ILMI. An example of the format and repetition interval of the update IP PDUs is given in Appendix B (interval and size) and Appendix C (format).

2.14. Bidirectional traffic

Bidirectional performance tests SHOULD be run with the same data rate being offered from each direction. The sum of the data rates should not exceed the theoretical limit for the media.

2.15. Single stream path

The full suite of tests SHOULD be run with the appropriate modifiers for a single receive and transmit port on the SUT. If the internal design of the SUT has multiple distinct pathways, for example, multiple interface cards each with multiple network ports, then all possible permutations of pathways SHOULD be tested separately. If multiple interconnected switches are tested, the test MUST specify routes, which allow only one path between source and destination ATM addresses.

2.16. Multi-port

Many switch products provide several network ports on the same interface module. Each port on an interface module SHOULD be stimulated in an identical manner. Specifically, half of the ports on each module SHOULD be receive ports and half SHOULD be transmit ports. For example if a SUT has two interface module each of which has four ports, two ports on each interface module be receive ports and two will be transmit ports. Each receive port MUST be offered the same data rate. The addresses in the input data streams SHOULD be set so that an IP PDU will be directed to each of the transmit ports in sequence. That is, all transmit ports will receive an identical distribution of IP PDUs from a particular receive port.

Consider the following 6 port SUT:

```

-----
-----| Rx A    Tx X|-----
-----| Rx B    Tx Y|-----
-----| Rx C    Tx Z|-----
-----

```

The addressing of the data streams for each of the inputs SHOULD be:

stream sent to Rx A:

IP PDU to Tx X, IP PDU to Tx Y, IP PDU to Tx Z

stream sent to Rx B:

IP PDU to Tx X, IP PDU to Tx Y, IP PDU to Tx Z

stream sent to Rx C

IP PDU to Tx X, IP PDU to Tx Y, IP PDU to Tx Z

Note: Each stream contains the same sequence of IP destination addresses; therefore, each transmit port will receive 3 IP PDUs simultaneously. This procedure ensures that the SUT will have to process multiple IP PDUs addressed to the same transmit port simultaneously.

The same configuration MAY be used to perform a bi-directional multi-stream test. In this case all of the ports are considered both receive and transmit ports. Each data stream MUST consist of IP PDUs whose addresses correspond to the ATM addresses all of the other ports.

2.17. Multiple protocols

This document does not address the issue of testing the effects of a mixed protocol environment other than to suggest that if such tests are wanted then PDUs SHOULD be distributed between all of the test protocols. The distribution MAY approximate the conditions on the network in which the SUT would be used.

2.18. Multiple IP PDU sizes

This document does not address the issue of testing the effects of a mixed IP PDU size environment other than to suggest that, if such tests are required, then IP PDU size SHOULD be evenly distributed among all of the PDU sizes listed in this document. The distribution MAY approximate the conditions on the network in which the SUT would be used.

2.19. Testing beyond a single SUT

In the performance testing of a single SUT, the paradigm can be described as applying some input to a SUT and monitoring the output. The results of which can be used to form a basis of characterization of that device under those test conditions.

This model is useful when the test input and output are homogeneous (e.g., 64-byte IP, AAL5 PDUs into the SUT; 64 byte IP, AAL5 PDUs out).

By extending the single SUT test model, reasonable benchmarks regarding multiple SUTs or heterogeneous environments may be collected. In this extension, the single SUT is replaced by a system of interconnected network SUTs. This test methodology would support the benchmarking of a variety of device/media/service/protocol combinations. For example, a configuration for a LAN-to-WAN-to-LAN test might be:

(1) ATM UNI -> SUT 1 -> BISUP -> SUT 2 -> ATM UNI

Or an extended LAN configuration might be:

(2) ATM UNI -> SUT 1 -> PNNI Network -> SUT 2 -> ATM UNI

In both examples 1 and 2, end-to-end benchmarks of each system could be empirically ascertained. Other behavior may be characterized through the use of intermediate devices. In example 2, the configuration may be used to give an indication of the effect of PNNI routing on IP throughput.

Because multiple SUTs are treated as a single system, there are limitations to this methodology. For instance, this methodology may yield an aggregate benchmark for a tested system. That benchmark alone, however, may not necessarily reflect asymmetries in behavior between the SUTs, latencies introduced by other apparatus (e.g., CSUs/DSUs, switches), etc.

Further, care must be used when comparing benchmarks of different systems by ensuring that the SUTs' features and configuration of the tested systems have the appropriate common denominators to allow comparison.

2.20. Maximum IP PDU rate

The maximum IP PDU rates that should be used when testing LAN connections SHOULD be the listed theoretical maximum rate for the IP PDU size on the media.

The maximum IP PDU rate that should be used when testing WAN connections SHOULD be greater than the listed theoretical maximum rate for the IP PDU size on that speed connection. The higher rate for WAN tests is to compensate for the fact that some vendors employ various forms of header compression.

A list of maximum IP PDU rates for LAN connections is included in Appendix B.

2.21. Bursty traffic

It is convenient to measure the SUT performance under steady state load; however, this is an unrealistic way to gauge the functioning of a SUT. Actual network traffic normally consists of bursts of IP PDUs.

Some of the tests described below SHOULD be performed with both constant bit rate, bursty Unspecified Bit Rate (UBR) Best Effort [AF-TM4.1] and Variable Bit Rate Non-real Time (VBR-nrt) Best Effort [AF-TM4.1]. The IP PDUs within a burst are transmitted with the minimum legitimate inter-IP PDU gap.

The objective of the test is to determine the minimum interval between bursts that the SUT can process with no IP PDU loss. Tests SHOULD be run with burst sizes of 10% of Maximum Burst Size (MBS), 20% of MBS, 50% of MBS and 100% MBS. Note that the number of IP PDUs in each burst will depend on the PDU size. For UBR, the MBS refers to the associated VBR traffic parameters.

2.22. Trial description

A particular test consists of multiple trials. Each trial returns one piece of information, for example the loss rate at a particular input IP PDU rate. Each trial consists of five of phases:

- a) If the SUT is a switch supporting PNNI, send the routing update to the SUT receive port and wait two seconds to be sure that the routing has settled.
- b) Send an ATM ARP PDU to determine the ATM address corresponding to the destination IP address. The formats of the ATM ARP PDU that should be used are shown in the Test Frame Formats document and MUST be in accordance with RFC 2225.
- c) Stimulate SUT with traffic load.
- d) Wait for two seconds for any residual IP PDUs to be received.
- e) Wait for at least five seconds for the SUT to restabilize.

2.23. Trial duration

The objective of the tests defined in this document is to accurately characterize the behavior of a particular piece of network equipment under varying traffic loads. The choice of test duration must be a compromise between this objective and keeping the duration of the benchmarking test suite within reasonable bounds. The SUT SHOULD be stimulated for at least 60 seconds. If this time period results in a high variance in the test results, the SUT SHOULD be stimulated for at least 300 seconds.

2.24. Address resolution

The SUT MUST be able to respond to address resolution requests sent by another SUT, an ATM ARP server or the test equipment in accordance with RFC 2225.

2.25. Synchronized Payload Bit Pattern.

Some measurements assume that both the transmitter and receiver payload information is synchronized. Synchronization MUST be achieved by supplying a known bit pattern to both the transmitter and receiver. This bit pattern MUST be one of the following: PRBS-15, PRBS-23, 0xFF00, or 0xAA55.

2.26. Burst Traffic Descriptors.

Some measurements require busty traffic patterns. These patterns MUST conform to one of the following traffic descriptors:

- 1) PCR=100% allotted line rate, SCR=50% allotted line rate, and MBS=8192
- 2) PCR=100% allotted line rate, SCR=50% allotted line rate, and MBS=4096
- 3) PCR=90% allotted line rate, SCR=50% allotted line rate, and MBS=8192
- 4) PCR=90% allotted line rate, SCR=50% allotted line rate, and MBS=4096
- 5) PCR=90% allotted line rate, SCR=45% allotted line rate, and MBS=8192
- 6) PCR=90% allotted line rate, SCR=45% allotted line rate, and MBS=4096
- 7) PCR=80% allotted line rate, SCR=40% allotted line rate, and MBS=65536
- 8) PCR=80% allotted line rate, SCR=40% allotted line rate, and MBS=32768

The allotted line rate refers to the total available line rate divided by the number of VCCs in use.

3. Performance Metrics

3.1. Physical Layer-SONET

3.1.1. Pointer Movements

3.1.1.1. Pointer Movement Propagation.

Objective: To determine that the SUT does not propagate pointer movements as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of IP PDUs at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The cell payload SHOULD contain valid IP PDUs. The IP PDUs MUST be encapsulated in AAL5.

- 3) Count the IP PDUs that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test, else lower the test device traffic rate until the counts are the same.
- 4) Inject one forward payload pointer movement. Verify that the SUT does not change the pointer.
- 5) Inject one forward payload pointer movement every 1 second. Verify that the SUT does not change the pointer.
- 6) Discontinue the payload pointer movement.
- 7) Inject five forward payload pointer movements every 1 second. Verify that the SUT does not change the pointer.
- 8) Discontinue the payload pointer movement.
- 9) Inject one backward payload pointer movement. Verify that the SUT does not change the pointer.
- 10) Inject one backward payload pointer movement every 1 second. Verify that the SUT does not change the pointer.
- 11) Discontinue the payload pointer movement.
- 12) Inject five backward payload pointer movements every 1 second. Verify that the SUT does not change the pointer.
- 13) Discontinue the payload pointer movement.

Reporting Format:

The results of the pointer movement propagation test SHOULD be reported in a form of a table. The rows SHOULD be labeled single pointer movement, one pointer movement per second, and five pointer movements per second. The columns SHOULD be labeled pointer movement and loss of pointer. The elements of the table SHOULD be either True or False, indicating whether the particular condition was observed for each test.

The table MUST also indicate the IP PDU size in octets and traffic rate in IP PDUs per second as generated by the test device.

3.1.1.2. Cell Loss due to Pointer Movement.

Objective: To determine if the SUT will drop cells due to pointer movements as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of cells at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The cell payload SHOULD contain valid IP PDUs. The IP PDUs MUST be encapsulated in AAL5.
- 3) Count the cells that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 4) Inject one forward payload pointer movement. Verify that the SUT does not drop any cells.
- 5) Inject one forward payload pointer movement every 1 second. Verify that the SUT does not drop any cells.
- 6) Discontinue the payload pointer movement.
- 7) Inject five forward payload pointer movements every 1 second. Verify that the SUT does not drop any cells.
- 8) Discontinue the payload pointer movement.
- 9) Inject one backward payload pointer movement. Verify that the SUT does not drop any cells.
- 10) Inject one backward payload pointer movement every 1 second. Verify that the SUT does not drop any cells.
- 11) Discontinue the payload pointer movement.
- 12) Inject five backward payload pointer movements every 1 second. Verify that the SUT does not drop any cells.
- 13) Discontinue the payload pointer movement.

Reporting Format:

The results of the cell loss due to pointer movement test SHOULD be reported in a form of a table. The rows SHOULD be labeled single pointer movement, one pointer movement per second, and five pointer movements per second. The columns SHOULD be labeled cell loss and number of cells lost. The elements of column 1 SHOULD be either True or False, indicating whether the particular condition was observed for each test. The elements of column 2 SHOULD be non-negative integers.

The table MUST also indicate the traffic rate in IP PDUs per second as generated by the test device.

3.1.1.3. IP Packet Loss due to Pointer Movement.

Objective: To determine if the SUT will drop IP packets due to pointer movements as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of IP packets at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 3) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 4) Inject one forward payload pointer movement. Verify that the SUT does not drop any packets.
- 5) Inject one forward payload pointer movement every 1 second. Verify that the SUT does not drop any packets.
- 6) Discontinue the payload pointer movement.
- 7) Inject five forward payload pointer movements every 1 second. Verify that the SUT does not drop any packets.
- 8) Discontinue the payload pointer movement.

- 9) Inject one backward payload pointer movement. Verify that the SUT does not drop any packets.
- 10) Inject one backward payload pointer movement every 1 second. Verify that the SUT does not drop any packets.
- 11) Discontinue the payload pointer movement.
- 12) Inject five backward payload pointer movements every 1 second. Verify that the SUT does not drop any packets.
- 13) Discontinue the payload pointer movement.

Reporting Format:

The results of the IP packet loss due to pointer movement test SHOULD be reported in a form of a table. The rows SHOULD be labeled single pointer movement, one pointer movement per second, and five pointer movements per second. The columns SHOULD be labeled packet loss and number of packets lost. The elements of column 1 SHOULD be either True or False, indicating whether the particular condition was observed for each test. The elements of column 2 SHOULD be non-negative integers.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device.

3.1.2. Transport Overhead (TOH) Error Count

3.1.2.1. TOH Error Propagation.

Objective: To determine that the SUT does not propagate TOH errors as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of IP PDUs at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The cell payload SHOULD contain valid IP PDUs. The IP PDUs MUST be encapsulated in AAL5.
- 3) Count the IP PDUs that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test, else lower the test device traffic rate until the counts are the same.

- 4) Inject one error in the first bit of the A1 and A2 Frameword. Verify that the SUT does not propagate the error.
- 5) Inject one error in the first bit of the A1 and A2 Frameword every 1 second. Verify that the SUT does not propagate the error.
- 6) Discontinue the Frameword error.
- 7) Inject one error in the first bit of the A1 and A2 Frameword for 4 consecutive IP PDUs in every 6 IP PDUs. Verify that the SUT indicates Loss of Frame.
- 8) Discontinue the Frameword error.

Reporting Format:

The results of the TOH error propagation test SHOULD be reported in a form of a table. The rows SHOULD be labeled single error, one error per second, and four consecutive errors every 6 IP PDUs. The columns SHOULD be labeled error propagated and loss of IP PDU. The elements of the table SHOULD be either True or False, indicating whether the particular condition was observed for each test.

The table MUST also indicate the IP PDU size in octets and traffic rate in IP PDUs per second as generated by the test device.

3.1.2.2. c TOH Error.

Objective: To determine if the SUT will drop cells due TOH Errors as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of cells at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The cell payload SHOULD contain valid IP PDUs. The IP PDUs MUST be encapsulated in AAL5.
- 3) Count the cells that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.

- 4) Inject one error in the first bit of the A1 and A2 Frameword. Verify that the SUT does not drop any cells.
- 5) Inject one error in the first bit of the A1 and A2 Frameword every 1 second. Verify that the SUT does not drop any cells.
- 6) Discontinue the Frameword error.
- 7) Inject one error in the first bit of the A1 and A2 Frameword for 4 consecutive IP PDUs in every 6 IP PDUs. Verify that the SUT does drop cells.
- 8) Discontinue the Frameword error.

Reporting Format:

The results of the Cell Loss due to TOH errors test SHOULD be reported in a form of a table. The rows SHOULD be labeled single error, one error per second, and four consecutive errors every 6 IP PDUs. The columns SHOULD be labeled cell loss and number of cells lost. The elements of column 1 SHOULD be either True or False, indicating whether the particular condition was observed for each test. The elements of column 2 SHOULD be non-negative integers.

The table MUST also indicate the traffic rate in IP PDUs per second as generated by the test device.

3.1.2.3. IP Packet Loss due to TOH Error.

Objective: To determine if the SUT will drop IP packets due to TOH errors as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of IP packets at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 3) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.

- 4) Inject one error in the first bit of the A1 and A2 Frameword. Verify that the SUT does not drop any packets.
- 5) Inject one error in the first bit of the A1 and A2 Frameword every 1 second. Verify that the SUT does not drop any packets.
- 6) Discontinue the Frameword error.
- 7) Inject one error in the first bit of the A1 and A2 Frameword for 4 consecutive IP PDUs in every 6 IP PDUs. Verify that the SUT does drop packets.
- 8) Discontinue the Frameword error.

Reporting Format:

The results of the IP packet loss due to TOH errors test SHOULD be reported in a form of a table. The rows SHOULD be labeled single error, one error per second, and four consecutive errors every 6 IP PDUs. The columns SHOULD be labeled packet loss and number of packets lost. The elements of column 1 SHOULD be either True or False, indicating whether the particular condition was observed for each test. The elements of column 2 SHOULD be non-negative integers.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device.

3.1.3. Path Overhead (POH) Error Count

3.1.3.1. POH Error Propagation.

Objective: To determine that the SUT does not propagate POH errors as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of IP PDUs at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The cell payload SHOULD contain valid IP PDUs. The IP PDUs MUST be encapsulated in AAL5.

- 3) Count the IP PDUs that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test, else lower the test device traffic rate until the counts are the same.
- 4) Inject one error in the B3 (Path BIP8) byte. Verify that the SUT does not propagate the error.
- 5) Inject one error in the B3 byte every 1 second. Verify that the SUT does not propagate the error.
- 6) Discontinue the POH error.

Reporting Format:

The results of the POH error propagation test SHOULD be reported in a form of a table. The rows SHOULD be labeled single error and one error per second. The columns SHOULD be labeled error propagated and loss of IP PDU. The elements of the table SHOULD be either True or False, indicating whether the particular condition was observed for each test.

The table MUST also indicate the IP PDU size in octets and traffic rate in IP PDUs per second as generated by the test device.

3.1.3.2. Cell Loss due to POH Error.

Objective: To determine if the SUT will drop cells due POH Errors as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of cells at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The cell payload SHOULD contain valid IP PDUs. The IP PDUs MUST be encapsulated in AAL5.
- 3) Count the cells that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 4) Inject one error in the B3 (Path BIP8) byte. Verify that the SUT does not drop any cells.

- 5) Inject one error in the B3 byte every 1 second. Verify that the SUT does not drop any cells.
- 6) Discontinue the POH error.

Reporting Format:

The results of the Cell Loss due to POH errors test SHOULD be reported in a form of a table. The rows SHOULD be labeled single error and one error per second. The columns SHOULD be labeled cell loss and number of cells lost. The elements of column 1 SHOULD be either True or False, indicating whether the particular condition was observed for each test. The elements of column 2 SHOULD be non-negative integers.

The table MUST also indicate the traffic rate in IP PDUs per second as generated by the test device.

3.1.3.3. IP Packet Loss due to POH Error.

Objective: To determine if the SUT will drop IP packets due to POH errors as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of IP packets at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 3) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 4) Inject one error in the B3 (Path BIP8) byte. Verify that the SUT does not drop any packets.
- 5) Inject one error in the B3 byte every 1 second. Verify that the SUT does not drop any packets.
- 6) Discontinue the POH error.

Reporting Format:

The results of the IP packet loss due to POH errors test SHOULD be reported in a form of a table. The rows SHOULD be labeled single error and one error per second. The columns SHOULD be labeled packet loss and number of packets lost. The elements of column 1 SHOULD be either True or False, indicating whether the particular condition was observed for each test. The elements of column 2 SHOULD be non-negative integers.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device.

3.2. ATM Layer

3.2.1. Two-Point Cell Delay Variation (CDV)

3.2.1.1. Test Setup

The cell delay measurements assume that both the transmitter and receiver timestamp information is synchronized. Synchronization SHOULD be achieved by supplying a common clock signal (minimum of 100 Mhz or 10 ns resolution) to both the transmitter and receiver. The maximum timestamp values MUST be recorded to ensure synchronization in the case of counter rollover. The cell delay measurements SHOULD utilize the O.191 cell (ITU-T-O.191) encapsulated in a valid IP packet. If the O.191 cell is not available, a test cell encapsulated in a valid IP packet MAY be used. The test cell MUST contain a transmit timestamp which can be correlated with a receive timestamp. A description of the test cell MUST be included in the test results. The description MUST include the timestamp length (in bits), counter rollover value, and the timestamp accuracy (in ns).

3.2.1.2. Two-point CDV/Steady Load/One VCC

Objective: To determine the SUT variation in cell transfer delay with one VCC as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).

- 3) Send a specific number of IP packets containing timestamps at a specific constant rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device.

Reporting Format:

The results of the Two-point CDV/Steady Load/One VCC test SHOULD be reported in a form of text, graph, and histogram.

The text results SHOULD display the numerical values of the CDV. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, maximum and minimum CDV during the test in us, and peak-to-peak CDV in us.

The graph results SHOULD display the cell delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell delay in us. The integration time per point MUST be indicated.

The histogram results SHOULD display the peak-to-peak cell delay. The x-coordinate SHOULD be the cell delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.1.3. Two-point CDV/Steady Load/Twelve VCCs

Objective: To determine the SUT variation in cell transfer delay with twelve VCCs as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the Two-point CDV/Steady Load/Twelve VCCs test SHOULD be reported in a form of text, graph, and histograms.

The text results SHOULD display the numerical values of the CDV. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CDV on each VCC during the test in us, and peak-to-peak CDV on each VCC in us.

The graph results SHOULD display the cell delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell delay for each VCC in ms. There SHOULD be 12 curves on the graph, one curves indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the peak-to-peak cell delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.1.4. Two-point CDV/Steady Load/Maximum VCCs

Objective: To determine the SUT variation in cell transfer delay with the maximum number VCCs supported on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the Two-point CDV/Steady Load/Maximum VCCs test SHOULD be reported in a form of text, graphs, and histograms.

The text results SHOULD display the numerical values of the CDV. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CDV on each VCC during the test in us, and peak-to-peak CDV on each VCC in us.

The graph results SHOULD display the cell delay values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell delay for each VCC in us. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the peak-to-peak cell delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.1.5. Two-point CDV/Bursty VBR Load/One VCC

Objective: To determine the SUT variation in cell transfer delay with one VCC as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific VBR through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device.

Reporting Format:

The results of the Two-point CDV/Bursty VBR Load/One VCC test SHOULD be reported in a form of text, graph, and histogram.

The text results SHOULD display the numerical values of the CDV. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, maximum and minimum CDV during the test in us, and peak-to-peak CDV in us.

The graph results SHOULD display the cell delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell delay in us. The integration time per point MUST be indicated.

The histogram results SHOULD display the peak-to-peak cell delay. The x-coordinate SHOULD be the cell delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.1.6. Two-point CDV/Bursty VBR Load/Twelve VCCs

Objective: To determine the SUT variation in cell transfer delay with twelve VCCs as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.

- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific VBR through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the Two-point CDV/Bursty VBR Load/Twelve VCCs test SHOULD be reported in a form of text, graph, and histograms.

The text results SHOULD display the numerical values of the CDV. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CDV on each VCC during the test in us, and peak-to-peak CDV on each VCC in us.

The graph results SHOULD display the cell delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell delay for each VCC in ms. There SHOULD be 12 curves on the graph, one curves indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the peak-to-peak cell delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.1.7. Two-point CDV/Bursty VBR Load/Maximum VCCs

Objective: To determine the SUT variation in cell transfer delay with the maximum number VCCs supported on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific VBR through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the Two-point CDV/Bursty VBR Load/Maximum VCCs test SHOULD be reported in a form of text, graphs, and histograms.

The text results SHOULD display the numerical values of the CDV. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on

each VCC during the test in positive integers, maximum and minimum CDV on each VCC during the test in us, and peak-to-peak CDV on each VCC in us.

The graph results SHOULD display the cell delay values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell delay for each VCC in us. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the peak-to-peak cell delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.1.8. Two-point CDV/Mixed Load/Three VCC's

Objective: To determine the SUT variation in cell transfer delay with three VCC's as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with three VCC's. Each VCC MUST be defined as a different Bearer class: one CBR, one UBR and one VBR. Each VCC SHOULD contain one VPI/VCI. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate.

Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCC's.

Reporting Format:

The results of the Two-point CDV/Mixed Load/Three VCC test SHOULD be reported in a form of text, graph, and histogram.

The text results SHOULD display the numerical values of the CDV. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, maximum and minimum CDV during the test in us, and peak-to-peak CDV in us.

The graph results SHOULD display the cell delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell delay in us. The integration time per point MUST be indicated.

The histogram results SHOULD display the peak-to-peak cell delay. The x-coordinate SHOULD be the cell delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.1.9. Two-point CDV/Mixed Load/Twelve VCCs

Objective: To determine the SUT variation in cell transfer delay with twelve VCCs as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCC's. Each VCC MUST be defined as one of the Bearer classes for a total of four CBR, four UBR and four VBR VCC's. Each VCC SHOULD contain one VPI/VCID. The VPI/VCID MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCID pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the Two-point CDV/Mixed Load/Twelve VCCs test SHOULD be reported in a form of text, graph, and histograms.

The text results SHOULD display the numerical values of the CDV. The values given SHOULD include: time period of test in s, test VPI/VCID values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CDV on each VCC during the test in us, and peak-to-peak CDV on each VCC in us.

The graph results SHOULD display the cell delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell delay for each VCC in ms. There SHOULD be 12 curves on the graph, one curves indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the peak-to-peak cell delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.1.10. Two-point CDV/Mixed Load/Maximum VCCs

Objective: To determine the SUT variation in cell transfer delay with the maximum number VCCs supported on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. Each VCC MUST be defined as one of the Bearer classes for a total of (max VCC/3) CBR, (max VCC/3) UBR and (max VCC/3) VBR VCC's. If the maximum number of VCC's is not divisible by 3, the total for each bearer class MUST be within 3 VCC's of each other. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the Two-point CDV/Mixed Load/Maximum VCCs test SHOULD be reported in a form of text, graphs, and histograms.

The text results SHOULD display the numerical values of the CDV. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CDV on each VCC during the test in us, and peak-to-peak CDV on each VCC in us.

The graph results SHOULD display the cell delay values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell delay for each VCC in us. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the peak-to-peak cell delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.2. Cell Error Ratio (CER)

3.2.2.1. Test Setup

The cell error ratio measurements assume that both the transmitter and receiver payload information is synchronized. Synchronization MUST be achieved by supplying a known bit pattern to both the transmitter and receiver. If this bit pattern is longer than the packet size, the receiver MUST synchronize with the transmitter before tests can be run.

3.2.2.2. CER/Steady Load/One VCC

Objective: To determine the SUT ratio of errored cells on one VCC in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a constant rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of bit errors at the receiver end of the test device.

Reporting Format:

The results of the CER/Steady Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CER for the entire test.

The graph results SHOULD display the cell error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CER. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.2.2.3. CER/Steady Load/Twelve VCCs

Objective: To determine the SUT ratio of errored cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of bit errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the CER/Steady Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CER for the entire test.

The graph results SHOULD display the cell error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.2.2.4. CER/Steady Load/Maximum VCCs

Objective: To determine the SUT ratio of errored cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of bit errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the CER/Steady Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CER for the entire test.

The graph results SHOULD display the cell error ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CER for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.2.2.5. CER/Bursty VBR Load/One VCC

Objective: To determine the SUT ratio of errored cells on one VCC in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.

- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific VBR rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of bit errors at the receiver end of the test device.

Reporting Format:

The results of the CER/Bursty VBR Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CER for the entire test.

The graph results SHOULD display the cell error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CER. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.2.2.6. CER/Bursty VBR Load/Twelve VCCs

Objective: To determine the SUT ratio of errored cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.

- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific VBR rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The PCR, SCR, and MBS must be indicated. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of bit errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the CER/Bursty VBR Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CER for the entire test.

The graph results SHOULD display the cell error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.2.2.7. CER/Bursty VBR Load/Maximum VCCs

Objective: To determine the SUT ratio of errored cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific VBR rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of bit errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the CER/Bursty VBR Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CER for the entire test.

The graph results SHOULD display the cell error ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CER for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.2.3. Cell Loss Ratio (CLR)

3.2.3.1. CLR/Steady Load/One VCC

Objective: To determine the SUT ratio of lost cells on one VCC in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets at a specific constant rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cells transmitted and received on the test device.

Reporting Format:

The results of the CLR/Steady Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CLR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CLR for the entire test.

The graph results SHOULD display the Cell Loss ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CLR. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.3.2. CLR/Steady Load/Twelve VCCs

Objective: To determine the SUT ratio of lost cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cells transmitted and received per VCC on the test device.

Reporting Format:

The results of the CLR/Steady Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CLR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CLR for the entire test.

The graph results SHOULD display the Cell Loss ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CLR for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.3.3. CLR/Steady Load/Maximum VCCs

Objective: To determine the SUT ratio of lost cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per

VPI. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCI's MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).

- 3) Send a specific number of IP packets at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cells transmitted and received per VCC on the test device.

Reporting Format:

The results of the CLR/Steady Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CLR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CLR for the entire test.

The graph results SHOULD display the Cell Loss ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CLR for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.3.4. CLR/Bursty VBR Load/One VCC

Objective: To determine the SUT ratio of lost cells on one VCC in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cells transmitted and received on the test device.

Reporting Format:

The results of the CLR/Bursty VBR Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CLR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CLR for the entire test.

The graph results SHOULD display the Cell Loss ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CLR. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.3.5. CLR/Bursty VBR Load/Twelve VCCs

Objective: To determine the SUT ratio of lost cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The PCR, SCR, and MBS must be indicated. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cells transmitted and received per VCC on the test device.

Reporting Format:

The results of the CLR/Bursty VBR Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CLR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on

the given VPI/VCI during the test in positive integers, and the CLR for the entire test.

The graph results SHOULD display the Cell Loss ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CLR for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.3.6. CLR/Bursty VBR Load/Maximum VCCs

Objective: To determine the SUT ratio of lost cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cells transmitted and received per VCC on the test device.

Reporting Format:

The results of the CLR/Bursty VBR Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CLR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CLR for the entire test.

The graph results SHOULD display the Cell Loss ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CLR for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.4. Cell Misinsertion Rate (CMR)

3.2.4.1. CMR/Steady Load/One VCC

Objective: To determine the SUT ratio of cell misinsertion on one VCC in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.

- 2) Configure the SUT and test device with one VCC. The VCC MUST be configured as either a CBR, VBR, or UBR connection. The VCC SHOULD contain one VPI/VCI. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets at a specific constant rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cell misinsertion errors at the receiver end of the test device.

Reporting Format:

The results of the CMR/Steady Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CMR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CMR for the entire test.

The graph results SHOULD display the Cell misinsertion rate values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CMR. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.4.2. CMR/Steady Load/Twelve VCCs

Objective: To determine the SUT rate of misinserted cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cell misinsertion errors at the receiver end of the test device per VCC.

Reporting Format:

The results of the CMR/Steady Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CMR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CMR for the entire test.

The graph results SHOULD display the Cell misinsertion rate values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CMR for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.4.3. CMR/Steady Load/Maximum VCCs

Objective: To determine the SUT rate of misinserted cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cell misinsertion errors at the receiver end of the test device per VCC.

Reporting Format:

The results of the CMR/Steady Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CMR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CMR for the entire test.

The graph results SHOULD display the Cell misinsertion rate values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total

length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CMR for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.4.4. CMR/Bursty VBR Load/One VCC

Objective: To determine the SUT rate of misinserted cells on one VCC in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cell misinsertion errors at the receiver end of the test device.

Reporting Format:

The results of the CMR/Bursty VBR Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CMR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CMR for the entire test.

The graph results SHOULD display the Cell misinsertion rate values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CMR. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.4.5. CMR/Bursty VBR Load/Twelve VCCs

Objective: To determine the SUT rate of misinserted cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The PCR, SCR, and MBS must be indicated. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cell misinsertion errors at the receiver end of the test device per VCC.

Reporting Format:

The results of the CMR/Bursty VBR Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CMR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CMR for the entire test.

The graph results SHOULD display the Cell misinsertion rate values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CMR for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.4.6. CMR/Bursty VBR Load/Maximum VCCs

Objective: To determine the SUT rate of misinserted cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per

VPI. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCI's MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.

- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of cell misinsertion errors at the receiver end of the test device per VCC.

Reporting Format:

The results of the CMR/Bursty VBR Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CMR. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CMR for the entire test.

The graph results SHOULD display the Cell misinsertion rate values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CMR for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5. CRC Error Ratio (CRC-ER)

3.2.5.1. CRC-ER/Steady Load/One VCC

Objective: To determine the SUT ratio of CRC errors on one VCC in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets at a specific constant rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received on the test device.

Reporting Format:

The results of the CRC-ER/Steady Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.2. CRC-ER/Steady Load/Twelve VCCs

Objective: To determine the SUT ratio of lost cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device.

Reporting Format:

The results of the CRC-ER/Steady Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.3. CRC-ER/Steady Load/Maximum VCCs

Objective: To determine the SUT ratio of lost cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device.

Reporting Format:

The results of the CRC-ER/Steady Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.4. CRC-ER/Bursty VBR Load/One VCC

Objective: To determine the SUT ratio of lost cells on one VCC in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCC. Since this test is not a throughput test, the

rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device.

Reporting Format:

The results of the CRC-ER/Bursty VBR Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCi value, total number of cells transmitted and received on the given VPI/VCi during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCi values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.5. CRC-ER/Bursty VBR Load/Twelve VCCs

Objective: To determine the SUT ratio of lost cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCis. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCis MUST not be one of the reserved ATM

signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.

- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The PCR, SCR, and MBS must be indicated. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device for all VCCs.

Reporting Format:

The results of the CRC-ER/Bursty VBR Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.6. CRC-ER/Bursty VBR Load/Maximum VCCs

Objective: To determine the SUT ratio of lost cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device for all VCCs.

Reporting Format:

The results of the CRC-ER/Bursty VBR Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values.

There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.7. CRC-ER/Bursty UBR Load/One VCC

Objective: To determine the SUT ratio of lost cells on one VCC in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as a UBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device.

Reporting Format:

The results of the CRC-ER/Bursty UBR Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.8. CRC-ER/Bursty UBR Load/Twelve VCCs

Objective: To determine the SUT ratio of lost cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC MUST be configured as a UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The PCR, SCR, and MBS must be indicated. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device for all VCCs.

Reporting Format:

The results of the CRC-ER/Bursty UBR Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCi value, total number of cells transmitted and received on the given VPI/VCi during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCi values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.9. CRC-ER/Bursty UBR Load/Maximum VCCs

Objective: To determine the SUT ratio of lost cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per

VPI. The VCC MUST be configured as a UBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.

- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device for all VCCs.

Reporting Format:

The results of the CRC-ER/Bursty UBR Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.10. CRC-ER/Bursty Mixed Load/Three VCC

Objective: To determine the SUT ratio of lost cells on three VCC's in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with three VCC's. Each VCC MUST be defined as a different Bearer class; one CBR, one UBR and one VBR. Each VCC SHOULD contain one VPI/VCI. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device.

Reporting Format:

The results of the CRC-ER/Bursty Mixed Load/Three VCC test SHOULD be reported in in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The

x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.11. CRC-ER/Bursty Mixed Load/Twelve VCCs

Objective: To determine the SUT ratio of lost cells on twelve VCCs in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCC's. Each VCC MUST be defined as one of the Bearer classes for a total of four CBR, four UBR and four VBR VCC's. Each VCC SHOULD contain one VPI/VCI. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device for all VCCs.

Reporting Format:

The results of the CRC-ER/Bursty Mixed Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.5.12. CRC-ER/Bursty Mixed Load/Maximum VCCs

Objective: To determine the SUT ratio of lost cells with the maximum number VCCs supported on the SUT in a transmission in relation to the total cells sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. Each VCC MUST be defined as one of the Bearer classes for a total of (max VCC/3) CBR, (max VCC/3) UBR and (max VCC/3) VBR VCC's. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of CRC errored cells received per VCC on the test device for all VCCs.

Reporting Format:

The results of the CRC-ER/Bursty Mixed Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, and the CRC-ER for the entire test.

The graph results SHOULD display the CRC Error ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the CRC-ER for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6. Cell Transfer Delay (CTD)

3.2.6.1. Test Setup

The cell transfer delay measurements assume that both the transmitter and receiver timestamp information is synchronized. Synchronization SHOULD be achieved by supplying a common clock signal (minimum of 100 Mhz or 10 ns resolution) to both the transmitter and receiver. The maximum timestamp values MUST be recorded to ensure synchronization in the case of counter rollover. The cell transfer delay measurements SHOULD utilize the 0.191 cell (ITU-T-O.191) encapsulated in a valid IP packet. If the 0.191 cell is not available, a test cell encapsulated in a valid IP packet MAY be used. The test cell

MUST contain a transmit timestamp which can be correlated with a receive timestamp. A description of the test cell MUST be included in the test results. The description MUST include the timestamp length (in bits), counter rollover value, and the timestamp accuracy (in ns).

3.2.6.2. CTD/Steady Load/One VCC

Objective: To determine the SUT variation in cell transfer delay with one VCC as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific constant rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device.

Reporting Format:

The results of the CTD/Steady Load/One VCC test SHOULD be reported in a form of text, graph, and histogram.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, minimum, maximum, and mean CTD during the test in us.

The graph results SHOULD display the cell transfer delay values. The x-coordinate SHOULD be the test run time in either seconds,

minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay in us. The integration time per point MUST be indicated.

The histogram results SHOULD display the cell transfer delay. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.3. CTD/Steady Load/Twelve VCCs

Objective: To determine the SUT variation in cell transfer delay with twelve VCCs as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the CTD/Steady Load/Twelve VCCs test SHOULD be reported in a form of text, graph, and histograms.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CTD on each VCC during the test in us, and mean CTD on each VCC in us.

The graph results SHOULD display the cell transfer delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay for each VCC in ms. There SHOULD be 12 curves on the graph, one curves indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the cell transfer delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.4. CTD/Steady Load/Maximum VCCs

Objective: To determine the SUT variation in cell transfer delay with the maximum number VCCs supported on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).

- 3) Send a specific number of IP packets containing timestamps at a specific constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the CTD/Steady Load/Maximum VCCs test SHOULD be reported in a form of text, graphs, and histograms.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CTD on each VCC during the test in us, and mean CTD on each VCC in us.

The graph results SHOULD display the cell transfer delay values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay for each VCC in us. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the cell transfer delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.5. CTD/Bursty VBR Load/One VCC

Objective: To determine the SUT variation in cell transfer delay with one VCC as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific VBR through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device.

Reporting Format:

The results of the CTD/Bursty VBR Load/One VCC test SHOULD be reported in a form of text, graph, and histogram.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, minimum, maximum, and mean CTD during the test in us.

The graph results SHOULD display the cell transfer delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay in us. The integration time per point MUST be indicated.

The histogram results SHOULD display the cell transfer delay. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.6. CTD/Bursty VBR Load/Twelve VCCs

Objective: To determine the SUT variation in cell transfer delay with twelve VCCs as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific VBR through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the CTD/Bursty VBR Load/Twelve VCCs test SHOULD be reported in a form of text, graph, and histograms.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CTD on each VCC during the test in us, and mean CTD on each VCC in us.

The graph results SHOULD display the cell transfer delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay for each VCC in ms. There SHOULD be 12 curves on the graph, one curves indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the cell transfer delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.7. CTD/Bursty VBR Load/Maximum VCCs

Objective: To determine the SUT variation in cell transfer delay with the maximum number VCCs supported on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific VBR through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be

greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the CTD/Bursty VBR Load/Maximum VCCs test SHOULD be reported in a form of text, graphs, and histograms.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CTD on each VCC during the test in us, and mean CTD on each VCC in us.

The graph results SHOULD display the cell transfer delay values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay for each VCC in us. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the cell transfer delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.8. CTD/Bursty UBR Load/One VCC

Objective: To determine the SUT variation in cell transfer delay with one VCC as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as a UBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific UBR through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device.

Reporting Format:

The results of the CTD/Bursty UBR Load/One VCC test SHOULD be reported in a form of text, graph, and histogram.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, minimum, maximum, and mean CTD during the test in us.

The graph results SHOULD display the cell transfer delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay in us. The integration time per point MUST be indicated.

The histogram results SHOULD display the cell transfer delay. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.9. CTD/Bursty UBR Load/Twelve VCCs

Objective: To determine the SUT variation in cell transfer delay with twelve VCCs as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as a UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific UBR through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the CTD/Bursty UBR Load/Twelve VCCs test SHOULD be reported in a form of text, graph, and histograms.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test

VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CTD on each VCC during the test in us, and mean CTD on each VCC in us.

The graph results SHOULD display the cell transfer delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay for each VCC in ms. There SHOULD be 12 curves on the graph, one curves indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the cell transfer delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.10. CTD/Bursty UBR Load/Maximum VCCs

Objective: To determine the SUT variation in cell transfer delay with the maximum number VCCs supported on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC MUST be configured as a UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps at a specific UBR through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the CTD/Bursty UBR Load/Maximum VCCs test SHOULD be reported in a form of text, graphs, and histograms.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CTD on each VCC during the test in us, and mean CTD on each VCC in us.

The graph results SHOULD display the cell transfer delay values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay for each VCC in us. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the cell transfer delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.11. CTD/Mixed Load/Three VCC's

Objective: To determine the SUT variation in cell transfer delay with three VCC's as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with three VCC's. Each VCC MUST be defined as a different Bearer class: one CBR, one UBR and one VBR. Each VCC SHOULD contain one VPI/VCI. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCC's.

Reporting Format:

The results of the CTD/Mixed Load/Three VCC test SHOULD be reported in a form of text, graph, and histogram.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of cells transmitted and received on the given VPI/VCI during the test in positive integers, minimum, maximum, and mean CTD during the test in us.

The graph results SHOULD display the cell transfer delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay in us. The integration time per point MUST be indicated.

The histogram results SHOULD display the cell transfer delay. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.12. CTD/Mixed Load/Twelve VCCs

Objective: To determine the SUT variation in cell transfer delay with twelve VCCs as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCC's. Each VCC MUST be defined as one of the Bearer classes for a total of four CBR, four UBR and four VBR VCC's. Each VCC SHOULD contain one VPI/VCI. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing timestamps through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the CTD/Mixed Load/Twelve VCCs test SHOULD be reported in a form of text, graph, and histograms.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CTD on each VCC during the test in us, and mean CTD on each VCC in us.

The graph results SHOULD display the cell transfer delay values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay for each VCC in ms. There SHOULD be 12 curves on the graph, one curves indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the cell transfer delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.2.6.13. CTD/Mixed Load/Maximum VCCs

Objective: To determine the SUT variation in cell transfer delay with the maximum number VCCs supported on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. Each VCC MUST be defined as one of the Bearer classes for a total of (max VCC/3) CBR, (max VCC/3) UBR and (max VCC/3) VBR VCC's. If the maximum number of VCC's is not divisible by 3, the total for each bearer class MUST be within 3 VCC's of each other. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).

- 3) Send a specific number of IP packets containing timestamps through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the packets timestamps at the transmitter and receiver ends of the test device for all VCCs.

Reporting Format:

The results of the CTD/Mixed Load/Maximum VCCs test SHOULD be reported in a form of text, graphs, and histograms.

The text results SHOULD display the numerical values of the CTD. The values given SHOULD include: time period of test in s, test VPI/VCI values, total number of cells transmitted and received on each VCC during the test in positive integers, maximum and minimum CTD on each VCC during the test in us, and mean CTD on each VCC in us.

The graph results SHOULD display the cell transfer delay values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the cell transfer delay for each VCC in us. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The histograms SHOULD display the cell transfer delay. There will be one histogram for each VCC. The x-coordinate SHOULD be the cell transfer delay in us with at least 256 bins. The y-coordinate SHOULD be the number of cells observed in each bin.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST also be indicated.

3.3. ATM Adaptation Layer (AAL) Type 5 (AAL5)

3.3.1. IP Packet Loss due to AAL5 Re-assembly Errors

Objective: To determine if the SUT will drop IP packets due AAL5 Re-assembly Errors as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of cells at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The cell payload SHOULD contain valid IP PDUs. The IP PDUs MUST be encapsulated in AAL5.
- 3) Count the cells that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 4) Inject one error in the first bit of the AAL5 payload. Verify that the SUT does not drop any AAL5 PDU's.
- 5) Discontinue the AAL5 payload error.
- 6) Inject one error in the first bit of the AAL5 header for 4 consecutive IP PDUs in every 6 IP PDUs. Verify that the SUT does drop the AAL5 PDU's.
- 7) Discontinue the AAL5 payload error.

Reporting Format:

The results of the AAL5 PDU Loss due to AAL5 PDU errors test SHOULD be reported in a form of a table. The rows SHOULD be labeled single error, one error per second, and four consecutive errors every 6 IP PDUs. The columns SHOULD be labeled AAL5 PDU loss and number of PDU's lost. The elements of column 1 SHOULD be either True or False, indicating whether the particular condition was observed for each test. The elements of column 2 SHOULD be non-negative integers.

The table MUST also indicate the traffic rate in IP PDUs per second as generated by the test device.

3.3.2. AAL5 Reassembly Time.

Objective: To determine the SUT AAL5 Reassembly Time as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional configuration.
- 2) Send a specific number of IP packets at a specific rate through the SUT. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5. The AAL5 PDU size is 65535 octets or 1365 ATM cells.
- 3) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 4) Given an AAL5 reassembly timer of 'x' seconds, where 'x' is the actual value of the AAL5 reassembly timer on the SUT, sent traffic at 1365 cells per 'x' seconds. The expected results are that no AAL5 PDU's will be dropped.
- 5) Send traffic at 1360 cells per 'x' seconds. The expected results are that all AAL5 PDU's will be dropped.

Reporting Format:

The results of the IP packet loss due to AAL5 reassembly timeout test SHOULD be reported in a form of a table. The rows SHOULD be labeled 1365 cells per 'x' seconds and 1360 cells per 'x' seconds. The columns SHOULD be labeled packet loss and number of packets lost. The elements of column 1 SHOULD be either True or False, indicating whether the particular condition was observed for each test. The elements of column 2 SHOULD be non-negative integers.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device, including the value of

3.3.3. AAL5 CRC Error Ratio.

3.3.3.1. Test Setup

The AAL5 CRC error ratio measurements assume that both the transmitter and receiver payload information is synchronized. Synchronization MUST be achieved by supplying a known bit pattern to both the transmitter and receiver. If this bit pattern is longer than the packet size, the receiver MUST synchronize with the transmitter before tests can be run.

3.3.3.2. AAL5-CRC-ER/Steady Load/One VCC

Objective: To determine the SUT ratio of AAL5 CRC PDU errors on one VCC in a transmission in relation to the total AAL5 PDU's sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCI. The VCC MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a constant rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of AAL5 CRC errors at the receiver end of the test device.

Reporting Format:

The results of the AAL5-CRC-ER/Steady Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the AAL5-CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of AAL5 PDU's transmitted and received on the given VPI/VCI during the test in positive integers, and the AAL5-CRC-ER for the entire test.

The graph results SHOULD display the AAL5 CRC error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the AAL5-CRC-ER. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.3.3.3. AAL5-CRC-ER/Steady Load/Twelve VCCs

Objective: To determine the SUT ratio of AAL5 CRC PDU errors on twelve VCC's in a transmission in relation to the total AAL5 PDU's sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate.

Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.

- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of AAL5 CRC errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the AAL5-CRC-ER/Steady Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the AAL5-CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of AAL5 PDU's transmitted and received on the given VPI/VCI during the test in positive integers, and the AAL5-CRC-ER for the entire test.

The graph results SHOULD display the AAL5 CRC error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the AAL5-CRC-ER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.3.3.4. AAL5-CRC-ER/Steady Load/Maximum VCCs

Objective: To determine the SUT ratio of AAL5 CRC PDU errors with the maximum number VCCs supported on the SUT in a transmission in relation to the total AAL5 PDU's sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs

supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. The VCC's MUST be configured as either a CBR, VBR, or UBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).

- 3) Send a specific number of IP packets containing one of the specified bit patterns at a constant rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of AAL5 CRC errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the AAL5-CRC-ER/Steady Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the AAL5-CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of AAL5 PDU's transmitted and received on the given VPI/VCI during the test in positive integers, and the AAL5-CRC-ER for the entire test.

The graph results SHOULD display the AAL5 CRC error ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the AAL5-CRC-ER for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.3.3.5. AAL5-CRC-ER/Bursty VBR Load/One VCC

Objective: To determine the SUT ratio of AAL5 CRC PDU errors on one VCC in a transmission in relation to the total AAL5 PDU's sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with one VCC. The VCC SHOULD contain one VPI/VCi. The VCC MUST be configured as either a CBR or VBR connection. The VPI/VCi MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific VBR rate through the SUT via the defined test VCC. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of AAL5 CRC errors at the receiver end of the test device.

Reporting Format:

The results of the AAL5-CRC-ER/Bursty VBR Load/One VCC test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the AAL5-CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCi value, total number of AAL5 PDU's transmitted and received on the given VPI/VCi during the test in positive integers, and the AAL5-CRC-ER for the entire test.

The graph results SHOULD display the AAL5 CRC error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The

x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the AAL5-CRC-ER. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.3.3.6. AAL5-CRC-ER/Bursty VBR Load/Twelve VCCs

Objective: To determine the SUT ratio of AAL5 CRC PDU errors on twelve VCC's in a transmission in relation to the total AAL5 PDU's sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCCs, using 1 VPI and 12 VCIs. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCIs MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.
- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific VBR rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The PCR, SCR, and MBS must be indicated. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of AAL5 CRC errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the AAL5-CRC-ER/Bursty VBR Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the AAL5-CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCi value, total number of AAL5 PDU's transmitted and received on the given VPI/VCi during the test in positive integers, and the AAL5-CRC-ER for the entire test.

The graph results SHOULD display the AAL5 CRC error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the AAL5-CRC-ER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCi values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.3.3.7. AAL5-CRC-ER/Bursty VBR Load/Maximum VCCs

Objective: To determine the SUT ratio of AAL5 CRC PDU errors with the maximum number VCCs supported on the SUT in a transmission in relation to the total AAL5 PDU's sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with the maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCis per VPI. The VCC's MUST be configured as either a CBR or VBR connection. The VPI/VCis MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]). The PCR, SCR, and MBS must be configured using one of the specified traffic descriptors.

- 3) Send a specific number of IP packets containing one of the specified bit patterns at a specific VBR rate through the SUT via the defined test VCCs. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of AAL5 CRC errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the AAL5-CRC-ER/Bursty VBR Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the AAL5-CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of AAL5 PDU's transmitted and received on the given VPI/VCI during the test in positive integers, and the AAL5-CRC-ER for the entire test.

The graph results SHOULD display the AAL5 CRC error ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the AAL5-CRC-ER for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.3.3.8. AAL5-CRC-ER/Mixed Load/Three VCC's

Objective: To determine the SUT ratio of AAL5 CRC PDU errors on three VCC's in a transmission in relation to the total AAL5 PDU's sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with three VCC's. Each VCC MUST be defined as a different Bearer class; one CBR, one UBR and one VBR. Each VCC SHOULD contain one VPI/VCI. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of AAL5 CRC errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the AAL5-CRC-ER/Bursty Mixed Load/Three VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the AAL5-CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of AAL5 PDU's transmitted and received on the given VPI/VCI during the test in positive integers, and the AAL5-CRC-ER for the entire test.

The graph results SHOULD display the AAL5 CRC error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the AAL5-CRC-ER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the

test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.3.3.9. AAL5-CRC-ER/Mixed Load/Twelve VCCs

Objective: To determine the SUT ratio of AAL5 CRC PDU errors on twelve VCC's in a transmission in relation to the total AAL5 PDU's sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with twelve VCC's. Each VCC MUST be defined as one of the Bearer classes for a total of four CBR, four UBR and four VBR VCC's. Each VCC SHOULD contain one VPI/VCI. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.
- 5) Record the number of AAL5 CRC errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the AAL5-CRC-ER/Bursty Mixed Load/Twelve VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the AAL5-CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCI value, total number of AAL5 PDU's transmitted and received on the given VPI/VCI during the test in positive integers, and the AAL5-CRC-ER for the entire test.

The graph results SHOULD display the AAL5 CRC error ratio values. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the AAL5-CRC-ER for each VCC. There should be 12 curves on the graph, on curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCI values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.3.3.10. AAL5-CRC-ER/Mixed Load/Maximum VCCs

Objective: To determine the SUT ratio of AAL5 CRC PDU errors with the maximum number VCCs supported on the SUT in a transmission in relation to the total AAL5 PDU's sent as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Configure the SUT and test device with maximum number of VCCs supported on the SUT. For example, if the maximum number of VCCs supported on the SUT is 1024, define 256 VPIs with 4 VCIs per VPI. Each VCC MUST be defined as one of the Bearer classes for a total of (max VCC/3) CBR, (max VCC/3) UBR and (max VCC/3) VBR VCC's. The VPI/VCI MUST not be one of the reserved ATM signaling channels (e.g., [0,5], [0,16]).
- 3) Send a specific number of IP packets containing one of the specified bit patterns through the SUT via the defined test VCCs. Each generated VCC stream MUST match the corresponding VCC Bearer class. All of the VPI/VCI pairs will generate traffic at the same traffic rate. Since this test is not a throughput test, the rate should not be greater than 90% of line rate. The IP PDUs MUST be encapsulated in AAL5.
- 4) Count the IP packets that are transmitted by the SUT on all VCCs to verify connectivity and load. If the count on the test device is the same on the SUT, continue the test; else lower the test device traffic rate until the counts are the same.

- 5) Record the number of AAL5 CRC errors at the receiver end of the test device for all VCCs.

Reporting Format:

The results of the AAL5-CRC-ER/Bursty Mixed Load/Maximum VCCs test SHOULD be reported in a form of text and graph.

The text results SHOULD display the numerical values of the AAL5-CRC-ER. The values given SHOULD include: time period of test in s, test VPI/VCi value, total number of AAL5 PDU's transmitted and received on the given VPI/VCi during the test in positive integers, and the AAL5-CRC-ER for the entire test.

The graph results SHOULD display the AAL5 CRC error ratio values. There will be (Max number of VCCs/10) graphs, with 10 VCCs indicated on each graph. The x-coordinate SHOULD be the test run time in either seconds, minutes or days depending on the total length of the test. The x-coordinate time SHOULD be configurable. The y-coordinate SHOULD be the AAL5-CRC-ER for each VCC. There SHOULD be no more than 10 curves on each graph, one curve indicated and labeled for each VCC. The integration time per point MUST be indicated.

The results MUST also indicate the packet size in octets, traffic rate in packets per second, and bearer class as generated by the test device. The VCC and VPI/VCi values MUST be indicated. The PCR, SCR, and MBS MUST be indicated. The bearer class of the created VCC MUST be indicated. The generated bit pattern MUST also be indicated.

3.4. ATM Service: Signaling

3.4.1. CAC Denial Time and Connection Establishment Time

Objective: To determine the CAC rejection time and Connection Establishment Time on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Create a UNI signaling setup message, as described in Appendix C, specifying a PCR which will not allow CAC to reject the call.

- 3) Send the UNI signaling setup message. Note the time the setup message was sent. Verify that the SVC has been setup with the correct parameters. Note the time the connect message was received
- 4) Create a UNI signaling setup message, as described in Appendix C, specifying a PCR which will allow CAC to reject the call.
- 5) Send the UNI signaling setup message. Note the time the setup message was sent. Verify that the SVC has been rejected with the correct cause code. Note the time the release complete message was received.
- 6) Compute the rejection time as the difference between the time the release complete message was received and the time setup message was send.

Reporting Format:

The results of the CAC Denial Time and Connection Establishment Time tests SHOULD be reported in a form of a table. The rows SHOULD be labeled call accepted and call rejected. The columns SHOULD be labeled time setup sent, time response received, and correct response. The elements of the columns 1 and 2 SHOULD be in seconds. The elements of column 3 SHOULD be either True or False, indicating whether the particular condition was observed for each test.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device.

3.4.2. Connection Teardown Time

Objective: To determine the Connection Teardown Time on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Create a UNI signaling setup message, as described in Appendix C, specifying a PCR which will not allow CAC to reject the call.
- 3) Send the UNI signaling setup message. Note the time the setup message was sent. Verify that the SVC has been setup with the correct parameters. Note the time the connect message was received

- 4) Create a UNI signaling release message, as described in Appendix C, specifying a cause code of normal call clearing.
- 5) Send the UNI signaling release message. Note the time the release message was sent. Verify that the SVC has been terminated with the correct cause code. Note the time the release complete message was received.
- 6) Compute the release time as the difference between the time the release complete message was received and the time release message was send.

Reporting Format:

The results of the Connection Teardown Time tests SHOULD be reported in a form of a table. The rows SHOULD be labeled call accepted and call released. The columns SHOULD be labeled time message sent, time response received, and correct response. The elements of the columns 1 and 2 SHOULD be in seconds. The elements of column 3 SHOULD be be either True or False, indicating whether the particular condition was observed for each test.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device.

3.4.3. Crankback Time

Objective: To determine the Crankback Time on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional passthrough configuration.
- 2) Create a PNNI signaling setup message, as described in Appendix C, specifying a DTL which is not blocked by the far end SUT.
- 3) Send the PNNI signaling setup message. Note the time the setup message was sent. Verify that the connect message has been received by the near-end switch. Note the time the connect message was received
- 4) Create a PNNI signaling setup message, as described in Appendix C, specifying a DTL which is blocked by the far end SUT.
- 5) Send the PNNI signaling release message. Note the time the release message was sent. Note the time the release complete

message was received. Note the time the near-end switch sends it's own PNNI setup message (referred to as the near-end setup message) specifying the non- blocked DTL.

- 6) Compute the crankback time as the difference between the time the near-end setup message was received and the time release message was send.

Reporting Format:

The results of the Crankback Time tests SHOULD be reported in a form of a table. The rows SHOULD be labeled DTL call accepted and call released. The columns SHOULD be labeled time message sent, time response received, and correct response. The elements of the columns 1 and 2 SHOULD be in seconds. The elements of column 3 SHOULD be either True or False, indicating whether the particular condition was observed for each test.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device.

3.4.4. Route Update Response Time

Objective: To determine the Route Update Response Time on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the uni-directional passthrough configuration.
- 2) Create a PNNI PTSE as described in Appendix C, specifying a routing topology. Verify that the routing tables on the far-end and near-end switches are empty.
- 3) Send the PTSE message to the far-end switch. Note the time the PTSE message was sent. Verify that the PTSE message has been received by the far-end switch. Note the time the PTSE message was received.
- 4) Create another PNNI PTSE as described in Appendix C, specifying a change in the routing topology. Verify that the routing tables on the far-end and near-end switches contain the previous PTSE routes.
- 5) Send the PTSE message to the far-end switch. Note the time the PTSE message was sent. Verify that the PTSE message has been received by the far-end switch. Note the time the PTSE message

was received. Note the time the PTSE was sent to the near-end switch. Note the time the PTSE message was received on the near-end switch.

- 6) Compute the Route Update Response time as the difference between the time the far-end PTSE message was sent and the time far-end PTSE message was received by the near-end.

Reporting Format:

The results of the Route Update Response Time tests SHOULD be reported in a form of a table. The rows SHOULD be labeled PTSE call accepted, far-end PTSE message send, and near-end message received. The columns SHOULD be labeled time message sent, time response received, and correct response. The elements of the columns 1 and 2 SHOULD be in seconds. The elements of column 3 SHOULD be either True or False, indicating whether the particular condition was observed for each test.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device.

3.5. ATM Service: ILMI

3.5.1. MIB Alignment Time

Objective: To determine the MIB Alignment Time on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Send a Cold Start message to the SUT. Note the time the message was sent to the SUT. Verify that the Cold Start message has been received by the SUT. Note the time the message was received.
- 3) Send a Get Request message to the SUT. Note the time the message was sent to the SUT. Verify that the Get Request message has been received by the SUT. Note the time the message was received.
- 4) After all MIB elements are exchanged, verify that the final Get Request message has been received by the SUT. Note the time the message was sent and received by the SUT.

- 5) Compute the MIB Alignment Time as the difference between the time the Cold Start message was sent and the time the final Get Request was received by the SUT.

Reporting Format:

The results of the MIB Alignment Time tests SHOULD be reported in a form of a table. The rows SHOULD be labeled Cold Start Send, Cold Start accepted, Final Get Request send, and Final Get Request received. The columns SHOULD be labeled time message sent, time response received, and correct response. The elements of the columns 1 and 2 SHOULD be in seconds. The elements of column 3 SHOULD be either True or False, indicating whether the particular condition was observed for each test.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device.

3.5.2. Address Registration Time

Objective: To determine the Address Registration Time on the SUT as defined in RFC 2761 "Terminology for ATM Benchmarking".

Procedure:

- 1) Set up the SUT and test device using the bi-directional configuration.
- 2) Send a Set Request message to the SUT. Note the time the message was sent to the SUT. Verify that the Set Request message has been received by the SUT. Note the time the message was received.
- 3) Send a Get Request message to the SUT. Note the time the message was sent to the SUT. Verify that the Get Request message has been received by the SUT. Note the time the message was received.
- 4) After all MIB elements are exchanged, verify that the final Get Request message has been received by the SUT. Note the time the message was sent and received by the SUT.
- 5) Compute the Address Registration Time as the difference between the time the Set Request message was sent and the time the final Get Request was received by the SUT.

Reporting Format:

The results of the Address Registration Time tests SHOULD be reported in a form of a table. The rows SHOULD be labeled Set Request Send, Set Request accepted, Final Get Request send, and Final Get Request received. The columns SHOULD be labeled time message sent, time response received, and correct response. The elements of the columns 1 and 2 SHOULD be in seconds. The elements of column 3 SHOULD be either True or False, indicating whether the particular condition was observed for each test.

The table MUST also indicate the packet size in octets and traffic rate in packets per second as generated by the test device.

4. Security Considerations

As this document is solely for the purpose of providing methodology and describes neither a protocol nor an implementation, there are no security considerations associated with this document.

5. Notices

The IETF takes no position regarding the validity or scope of any intellectual property or other rights that might be claimed to pertain to the implementation or use of the technology described in this document or the extent to which any license under such rights might or might not be available; neither does it represent that it has made any effort to identify any such rights. Information on the IETF's procedures with respect to rights in standards-track and standards-related documentation can be found in BCP-11. Copies of claims of rights made available for publication and any assurances of licenses to be made available, or the result of an attempt made to obtain a general license or permission for the use of such proprietary rights by implementors or users of this specification can be obtained from the IETF Secretariat.

The IETF invites any interested party to bring to its attention any copyrights, patents or patent applications, or other proprietary rights which may cover technology that may be required to practice this standard. Please address the information to the IETF Executive Director.

6. References

- [RFC2544] Bradner, S. and J. McQuaid, "Benchmarking Methodology for Network Interconnect Devices", RFC 2544, March 1999.
- [RFC2225] Laubach, M. and J. Halpern, "Classical IP and ARP over ATM", RFC 2225, April 1998.
- [RFC2761] Dunn, J. and C. Martin, "Terminology for ATM Benchmarking", RFC 2761, February 2000.
- [AF-ILMI4.0] ATM Forum Integrated Local Management Interface Version 4.0, af-ilmi-0065.000, September 1996.
- [AF-TEST-0022] Introduction to ATM Forum Test Specifications, af-test-0022.00, December 1994.
- [AF-TM4.1] ATM Forum, Traffic Management Specification Version 4.1, af-tm-0121.00, April 1996.
- [AF-UNI3.1] ATM Forum, User Network Interface Specification Version 3.1, September 1994.
- [AF-UNI4.0] ATM Forum, User Network Interface Specification Version 4.0, July 1996.

7. Authors' Addresses

Jeffrey Dunn
Advanced Network Consultants, Inc.
4214 Crest Place
Ellicott City, MD 21043, USA

Phone: +1 (410) 750-1700
EMail: Jeffrey.Dunn@worldnet.att.net

Cynthia Martin
Advanced Network Consultants, Inc.
4214 Crest Place
Ellicott City, MD 21043, USA

Phone: +1 (410) 750-1700
EMail: Cynthia.E.Martin@worldnet.att.net

Appendix A: Ranges

ATM NSAP Network Prefix.

```

39 0000 0000 0000 0000 0000 0000-39 0000 0000 0000 0000 0000 00FF
39 0000 0000 0000 0000 0001 0000-39 0000 0000 0000 0000 0001 00FF
39 0000 0000 0000 0001 0000 0000
39 0000 0000 0000 0002 0020 0000
39 0000 0000 0300 0002 0030 0000
39 0000 0000 4000 0002 0060 0000
39 0000 0006 0060 0002 0030 0000
39 0000 0006 0050 0002 0030 0000
39 0000 0009 0300 0002 0030 0000
39 0000 00A0 0300 0002 0030 0000
39 0000 0B00 0300 0002 0030 0000
39 0000 C000 0300 0002 0030 0000

```

ATM NSAP End System Identifier.

```

1111 1111 1111 00-1111 1111 11FF 00
2222 2222 2000 00-2222 2222 2222 00
9999 999A 0000 00-9999 999C 0000 00

```

Appendix B: Rates

PNNI Routing Update Size.

- 1) 1 PNNI routing entry update on non-aggregated addresses
- 2) 2 PNNI routing entry updates on non-aggregated addresses
- 3) 5 PNNI routing entry updates on non-aggregated addresses
- 4) 1 % of total available bandwidth or 1 Mb/s, whichever is less on non- aggregated addresses
- 5) 1 % of total available bandwidth or 1 Mb/s, whichever is less on of non-aggregated addresses and of aggregated addresses
- 6) 1 % of total available bandwidth or 1 Mb/s, whichever is less on aggregated addresses
- 7) 2 % of total available bandwidth or 2 Mb/s, whichever is less on non- aggregated addresses
- 8) 2 % of total available bandwidth or 2 Mb/s, whichever is less on of non-aggregated addresses and of aggregated addresses
- 9) 2 % of total available bandwidth or 2 Mb/s, whichever is less on aggregated addresses

PNNI Routing Update Repetition Interval.

Repetition Interval begins after initial PNNI routing table stabilizes.

- 1) 1 update every 1 hour, for 24 hours
- 2) 1 update every 30 minutes, for 24 hours
- 3) 1 update every 5 minutes, for 1 hour
- 4) 1 update every 1 minute, for 15 minutes
- 5) 1 update every 30 seconds, for 5 minutes
- 6) 1 update every 30 seconds, for 1 minute
- 7) 1 update every 1 second, for 30 seconds

Maximum WAN Connection rates in packets per second (pps):

	25.6	OC-3c	OC-12c
IP Packet Size			
octets/cells			
44/2	30188	176603	706412
64/2	30188	176603	706412
128/3	20125	117735	470940
256/6	10062	58867	235468
1024/22	2744	16054	64216
1518/32	1886	11037	44148
2048/43	1404	8214	32856
4472/94	642	3757	15028
9180/192	314	1839	7356

Maximum LAN Connection rates in packets per second (pps):

	DS-1	DS-3	E1	E3
IP Packet Size				
octets/cells				
44/2	1811	52133	2340	40000
64/2	1811	52133	2340	40000
128/3	1207	34755	1560	26666
256/6	603	17377	780	13333
1024/22	164	4739	212	3636
1518/32	113	3258	146	2500
2048/43	84	2424	108	1860
4472/94	38	1109	49	851
9180/192	18	543	24	416

Notes: 1. PDU size in cells is computed based on ceiling((PDU size in octets + 16) / 48). This assumes an 8 octet LLC/SNAP header and an 8 octet AAL/5 trailer.

2. Due to the number of possible configurations, IMA pps rates are not listed, but may be derived from the following formula: floor (IDCR/cells per packet), where cells per packet is computed as in note 1.

3. The following cell rates were used: DS-1 = 3622 cps (using ATM TC) E1 = 4681 cps 25.6 Mb/s = 60377 cps E3 = 80000 cps (using ATM TC) DS-3 = 104266 cps (using ATM TC) OC-3c = 353207 cps OC-12c = 1412828 cps

Appendix C: PDU's

TCP/IP over ATM Example 1.

LLC:	DSAP	0xAA (SNAP-SAP)
	SSAP	0xAA (SNAP-SAP)
	Control	0x03 (Unnumbered Information)
SNAP:	OUI	0x00-00-00 (Ethertype)
	PID	0x0800 (Internet Protocol)
IP:	Version = 4	
	Header length = 20	
	Type of service = 0	
	000. Precedence = Routine(0)	
	...0 Delay = Normal (0)	
 0... Throughput = Normal (0)	
0.. Reliability = Normal (0)	
	Packet length = 40	
	Id = 0	
	Fragmentation Info = 0x0000	
	.0.. Don't Fragment Bit = FALSE	
	..0. More Fragments Bit = FALSE	
	...0 0000 0000 0000 Fragment offset = 0	
	Time to live = 255	
	Protocol = TCP (6)	
	Header checksum = F9CF	
	Source address = 15.19.209.236	
	Destination address = 15.19.209.237	
TCP:	Source port = smtp (25)	
	Destination port = smtp (25)	
	Sequence number = 1	
	Ack number = 0	
	Data offset = 20	
	Flags = 0x02	
	..0. URGENT Flag = FALSE	
	...0 ACK Flag = FALSE	

```

.... 0... PUSH Flag = FALSE
.... .0.. RST Flag = FALSE
.... ..1. SYN Flag = TRUE
.... ...0 FIN Flag = FALSE
Window = 0
Checksum = EDAF
Urgent pointer = 00000000

```

TCP/IP over ATM Example 2.

```

LLC:      DSAP      0xAA (SNAP-SAP)
          SSAP      0xAA (SNAP-SAP)
          Control    0x03 (Unnumbered Information)
SNAP:     OUI       0x00-00-00 (Ethernet type)
          PID       0x0800 (Internet Protocol)
IP:       Version = 4
          Header length = 20
          Type of service = 0
              000. .... Precedence = Routine(0)
              ...0 .... Delay = Normal (0)
              .... 0... Throughput = Normal (0)
              .... .0.. Reliability = Normal (0)
          Packet length = 40
          Id = 0
          Fragmentation Info = 0x0000
              .0.. .... Don't Fragment Bit = FALSE
              ..0. .... More Fragments Bit = FALSE
              ...0 0000 0000 0000 Fragment offset = 0
          Time to live = 255
          Protocol = TCP (6)
          Header checksum = F9CF
          Source address = 15.19.209.236
          Destination address = 15.19.209.237
TCP:      Source port = ftp-data (20)
          Destination port = 2000
          Sequence number = 1
          Ack number = 0
          Data offset = 20
          Flags = 0x02
              ..0. .... URGENT Flag = FALSE
              ...0 .... ACK Flag = FALSE
              .... 0... PUSH Flag = FALSE
              .... .0.. RST Flag = FALSE
              .... ..1. SYN Flag = TRUE
              .... ...0 FIN Flag = FALSE
          Window = 0
          Checksum = E5FD
          Urgent pointer = 00000000

```

UDP/IP over ATM Example.

```

LLC:  DSAP          0xAA (SNAP-SAP)
      SSAP          0xAA (SNAP-SAP)
      Control       0x03 (Unnumbered Information)
SNAP:  OUI          0x00-00-00 (Ethernet type)
      PID           0x0800 (Internet Protocol)
IP:    Version = 4
      Header length = 20
      Type of service = 0
          000. .... Precedence = Routine(0)
          ...0 .... Delay = Normal (0)
          .... 0... Throughput = Normal (0)
          .... .0.. Reliability = Normal (0)
      Packet length = 28
      Id = 0
      Fragmentation Info = 0x0000
          .0.. .... .... Don't Fragment Bit = FALSE
          ..0. .... .... More Fragments Bit = FALSE
          ...0 0000 0000 0000 Fragment offset = 0
      Time to live = 255
      Protocol = ICMP (1)
      Header checksum = F9E0
      Source address = 15.19.209.236
      Destination address = 15.19.209.237
ICMP:  Type = Echo request (8)
      Code = 0
      Checksum = F7FF
      Identifier = 0 (0x0)
      Sequence Number = 0 (0x0)

```

RIP Routing Update over ATM.

```

-- DATAGRAM HEADER
  offset data (hex)          description
  00      FF FF FF FF FF FF  dest MAC address is broadcast
  06      xx xx xx xx xx xx  source hardware address
  12      08 00              type

-- IP HEADER
  14      45                IP version - 4, header length (4
byte units) - 5
  15      00                service field
  16      00 EE              total length
  18      00 00              ID
  20      40 00              flags (3 bits) 4 (do not
fragment),
                                fragment offset-0
  22      0A                TTL

```

```

23      11                                protocol - 17 (UDP)
24      C4 8D                            header checksum
26      xx xx xx xx                      source IP address
30      xx xx xx                        destination IP address
33      FF                                host part = FF for broadcast

-- UDP HEADER
34      02 08                            source port 208 = RIP
36      02 08                            destination port 208 = RIP
38      00 DA                            UDP message length
40      00 00                            UDP checksum

-- RIP packet
42      02                                command = response
43      01                                version = 1
44      00 00                            0

-- net 1
46      00 02                            family = IP
48      00 00                            0
50      xx xx xx                        net 1 IP address
53      00                                net not node
54      00 00 00 00                    0
58      00 00 00 00                    0
62      00 00 00 07                    metric 7

-- net 2
66      00 02                            family = IP
68      00 00                            0
70      xx xx xx                        net 2 IP address
73      00                                net not node
74      00 00 00 00                    0
78      00 00 00 00                    0
82      00 00 00 07                    metric 7

-- net 3
86      00 02                            family = IP
88      00 00                            0
90      xx xx xx                        net 3 IP address
93      00                                net not node
94      00 00 00 00                    0
98      00 00 00 00                    0
102     00 00 00 07                    metric 7

-- net 4
106     00 02                            family = IP
108     00 00                            0

```

```

110      xx xx xx          net 4 IP address
113      00              net not node
114      00 00 00 00      0
118      00 00 00 00      0
122      00 00 00 07      metric 7

-- net 5
126      00 02          family = IP
128      00 00          0
130      00            net 5 IP address
133      00            net not node
134      00 00 00 00      0
138      00 00 00 00      0
142      00 00 00 07      metric 7

-- net 6
146      00 02          family = IP
148      00 00          0
150      xx xx xx      net 6 IP address
153      00            net not node
154      00 00 00 00      0
158      00 00 00 00      0
162      00 00 00 07      metric 7

```

UNI 3.1 Signaling Setup Message Example. PCR will not allow CAC to reject the call.

```

Protocol Discriminator      : Q.93B UNI call control
Call Reference Length       : 3
Call Reference Flag        : orig
Call Reference Value       : 0
Message Type               : SETUP
Ext                        : last octet
Action Indicator           : clear call
Message Length             : 50
Information Element ID     : ATM Traffic Descriptor
Ext                        : last octet
Coding Standard            : ITU-T standard
Action Indicator           : clear call
IE Length                  : 9
Cell Rate Subfield ID     : forward peak CR(CLP=0+1)
Forward Peak Cell Rate    : 1
Cell Rate Subfield ID     : backward peak CR(CLP=0+1)
Backward Peak Cell Rate   : 1
Cell Rate Subfield ID     : best effort indicator
Information Element ID     : Broadband Bearer Capability
Ext                        : last octet
Coding Standard            : ITU-T standard

```



```

Action Indicator      : clear call
IE Length            : 2
Ext                  : last octet
Bearer Class         : BCOB-X
Ext                  : last octet
Clipping Susceptibility : not susceptible to clipping
User Plane Connection CFG : point-to-point
Information Element ID : Called Party Number
Ext                  : last octet
Coding Standard      : ITU-T standard
Action Indicator      : clear call
IE Length            : 21
Ext                  : last octet
Addressing/Numbering Plan : ISO NSAP addressing
ISO NSAP Address Octets : 39000000000000000000000001111111111100
Information Element ID : Quality of Service Parameter
Ext                  : last octet
Coding Standard      : ITU-T standard
Action Indicator      : clear call
IE Length            : 2
QoS Class Forward     : QoS class 0 - unspecified
QoS Class Backward    : QoS class 0 - unspecified

```

UNI 3.1 Signaling Setup Message Reject Example. PCR will allow CAC to reject the call.

```

Protocol Discriminator      : Q.93B UNI call control
Call Reference Length      : 3
Call Reference Flag        : orig
Call Reference Value       : 0
Message Type               : SETUP
Ext                        : last octet
Action Indicator           : clear call
Message Length             : 50
Information Element ID     : ATM Traffic Descriptor
Ext                        : last octet
Coding Standard            : ITU-T standard
Action Indicator           : clear call
IE Length                  : 8
Cell Rate Subfield ID     : forward peak CR(CLP=0+1)
Forward Peak Cell Rate     : 300000
Cell Rate Subfield ID     : backward peak CR(CLP=0+1)
Backward Peak Cell Rate   : 300000
Information Element ID     : Broadband Bearer Capability
Ext                        : last octet
Coding Standard            : ITU-T standard
Flag                       : not significant
Action Indicator           : clear call

```

```

IE Length          : 3
Ext                : another octet
Bearer Class       : BCOB-X
Ext                : last octet
Traffic Type       : constant bit rate
Timing Requirements : end-to-end timing required
Ext                : last octet
Clipping Susceptibility : not susceptible to clipping
User Plane Connection CFG : point-to-point
Information Element ID : Called Party Number
Ext                : last octet
Coding Standard    : ITU-T standard
Action Indicator    : clear call
IE Length          : 21
Ext                : last octet
Addressing/Numbering Plan : ISO NSAP addressing
ISO NSAP Address Octets : 3900000000000000000000000000000011111111111100
Information Element ID : Quality of Service Parameter
Ext                : last octet
Coding Standard    : ITU-T standard
Action Indicator    : clear call
IE Length          : 2
QoS Class Forward   : QoS class 0 - unspecified
QoS Class Backward  : QoS class 0 - unspecified

```

UNI 3.1 Signaling Release Message, specifying a cause code of normal call clearing.

```

Protocol Discriminator : Q.93B UNI call control
Call Reference Length   : 3
Call Reference Flag     : orig
Call Reference Value    : 0
Message Type            : RELEASE
Ext                     : last octet
Action Indicator        : clear call
Message Length          : 6
Information Element ID  : Cause
Ext                     : last octet
Coding Standard         : ITU-T standard
Action Indicator        : clear call
IE Length              : 2
Ext                     : last octet
Location                : user
Ext                     : last octet
Cause Value             : NE:normal call clearing

```

PNNI Signaling Setup Message, specifying a DTL which is not blocked by the far end SUT.

```

Protocol Discriminator      : PNNI signalling
Call Reference Length      : 3
Call Reference Flag        : from
Message Type               : SETUP
Ext                         : last octet
Pass Along Request         : no pass along request
Action Indicator           : clear call
Message Length             : 56
Information Element ID     : ATM Traffic Descriptor
Ext                         : last octet
Coding Standard            : ITU-T standardized
Pass Along Request         : no pass along request
Action Indicator           : clear call
IE Length                  : 0
Information Element ID     : Broadband Bearer Capability
Ext                         : last octet
Coding Standard            : ITU-T standardized
Pass Along Request         : no pass along request
Action Indicator           : clear call
IE Length                  : 3
Ext                         : another octet
Bearer Class               : BCOB-X
Ext                         : last octet
ATM Transfer Capability    : reserved for bwd compatibility
Ext                         : last octet
Clipping Susceptibility    : not susceptible to clipping
User Plane Connection cfg  : point-to-point
Information Element ID     : Called Party Number
Ext                         : last octet
Coding Standard            : ITU-T standardized
Pass Along Request         : no pass along request
Action Indicator           : clear call
IE Length                  : 8
Ext                         : last octet
Type of Number             : unknown
Addressing/Numbering Plan  : ATM endsystem address
ATM Endsystem Address Oct  : 1111111111101
Information Element ID     : Designated Transit List
Ext                         : last octet
Coding Standard            : ATM Forum specific
Pass Along Request         : no pass along request
Action Indicator           : clear call
IE Length                  : 29
Current Transit Pointer    : 0
Logical Node/Port Indicat  : Logical Node/Port Indicator
Logical Node Identifier    : 390000000000000000000000001111111111100

```

PNNI Signaling Setup Message Reject, specifying a DTL which is blocked by the far end SUT.

```

Protocol Discriminator      : PNNI signalling
  Call Reference Length    : 3
  Call Reference Flag      : from
  Call Reference Value     : 0
  Message Type            : SETUP
  Ext                     : last octet
  Pass Along Request      : no pass along request
  Action Indicator        : clear call
  Message Length          : 56
  Information Element ID   : ATM Traffic Descriptor
  Ext                     : last octet
  Coding Standard         : ITU-T standardized
  Pass Along Request      : no pass along request
  Action Indicator        : clear call
  IE Length               : 0
  Information Element ID   : Broadband Bearer Capability
  Ext                     : last octet
  Coding Standard         : ITU-T standardized
  Pass Along Request      : no pass along request
  Action Indicator        : clear call
  IE Length               : 3
  Bearer Class            : BCOB-X
  Ext                     : last octet
  ATM Transfer Capability : reserved for bwd compatibility
  Ext                     : last octet
  Clipping Susceptibility : not susceptible to clipping
  User Plane Connection cfg : point-to-point
  Information Element ID   : Called Party Number
  Ext                     : last octet
  Coding Standard         : ITU-T standardized
  Pass Along Request      : no pass along request
  Action Indicator        : clear call
  IE Length               : 8
  Ext                     : last octet
  Addressing/Numbering Plan : ATM endsystem address
  ATM Endsystem Address Oct : 1111111111101
  Information Element ID   : Designated Transit List
  Ext                     : last octet
  Coding Standard         : ATM Forum specific
  Pass Along Request      : no pass along request
  Action Indicator        : clear call
  IE Length               : 29
  Current Transit Pointer  : 0
  Logical Node/Port Indicat : Logical Node/Port Indicator
  Logical Node Identifier  : 39000000000000000000000001111111111100

```

PNNI Far End Request Message.

Header:	Packet Type	5	(PTSE REQUEST)
	Packet Length	40	
	Protocol Version	1	
	Newest Version Supported	1	
	Oldest Version Supported	0	
	Reserved	0	
IG:	Information Group Type	513	(Requested PTSE Header)
	Information Group Length	32	
	Originating Node ID	00013900-00000000-00000000-00000011-11111111-1100	
	PTSE Request Count	1	
	PTSE Identifier	0	

PNNI PTSE, specifying a routing topology.

Header:	Packet Type	4	(DATABASE SUMMARY)
	Packet Length	76	
	Protocol Version	1	
	Newest Version Supported	1	
	Oldest Version Supported	0	
	Reserved	0	
	Initialize (I)Bit	1	(during init. of DB syn process)
	More (M)Bit	1	(PTSEs to summarize)
	Master (MS)Bit	1	(both nodes)
	Reserved	0	
	Reserved	0	
	DS Sequence Number	0	
IG:	Information Group Type	512	(Nodal PTSE Summaries)
	Information Group Length	60	
	Originating Node ID	00013900-00000000-00000000-00000011-11111111-1100	
	Originating Node's Peer Group	00000000-00000000-00000000-0001	
	Reserved	0	
	PTSE Summary Count	1	
	PTSE Type	0	
	Reserved	0	
	PTSE Identifier	0	
	PTSE Sequence Number	0	
	PTSE Checksum	0	
	PTSE Remaining Lifetime	0	

PNNI PTSE Update, specifying a change in the routing topology.

```

Header:  Packet Type                2 (PTSP)
         Packet Length              96
         Protocol Version            1
         Newest Version Supported    1
         Oldest Version Supported    0
         Reserved                    0
         Originating Node ID
           00013900-00000000-00000000-00000011-11111111-1100
         Originating Node's Peer Group 00000000-00000000-00000000-
           0001
IG:      Information Group Type      64 (PTSE)
         Information Group Length    52
         PTSE Type                   0
         Reserved                    0
         PTSE Identifier             0
         PTSE Sequence Number        0
         PTSE Checksum               42252
         PTSE Remaining Lifetime     3600
IG:      Information Group Type      224 (Internal Reachable ATM
         Addresses)
         Information Group Length    32
         VP Capability Flag          1 (VPCs supported)
         Reserved                    0
         Reserved                    0
         Port ID                     0
         Scope of Advertisement      96
         Address Information Length  14
         Address Information Count    1
         Prefix Length               13
         Reachable Address Prefix    39000000-00000000-00000000-01

```

Full Copyright Statement

Copyright (C) The Internet Society (2001). All Rights Reserved.

This document and translations of it may be copied and furnished to others, and derivative works that comment on or otherwise explain it or assist in its implementation may be prepared, copied, published and distributed, in whole or in part, without restriction of any kind, provided that the above copyright notice and this paragraph are included on all such copies and derivative works. However, this document itself may not be modified in any way, such as by removing the copyright notice or references to the Internet Society or other Internet organizations, except as needed for the purpose of developing Internet standards in which case the procedures for copyrights defined in the Internet Standards process must be followed, or as required to translate it into languages other than English.

The limited permissions granted above are perpetual and will not be revoked by the Internet Society or its successors or assigns.

This document and the information contained herein is provided on an "AS IS" basis and THE INTERNET SOCIETY AND THE INTERNET ENGINEERING TASK FORCE DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY WARRANTY THAT THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OR ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

Acknowledgement

Funding for the RFC Editor function is currently provided by the Internet Society.

