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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Methods for Testing and Specification (MTS).

Introduction

The present document is an overview on current trends on testing matters (Integration Testing, Interconnection testing, Conformance Testing) and has purely informative purposes. It may be used for illustrative and tutoring purposes.

1 Scope

The goal of the present document is to provide basic information on the goals and possible areas of application of the Network Integration/Interconnection Testing (NIT) methodology.

NIT is a network specific testing approach, originally defined by EURESCOM, according to which NIT Test Suites can be designed, implemented, and eventually used for tests and trials, in different network contexts and with different goals.

NIT can be used, at an extent, also for Network Interconnection Testing purposes, following bilateral agreements from Network Operators, and could be considered in a future in the framework of a possible regulation of such issues.

NIT encompasses two basic types of testing, End to End and Node to Node, which are both discussed in detail in the present document.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] ISO/IEC 9646-1 (1994): "Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 1: General concepts".

[2] ISO/IEC 9646-2 (1994): "Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 2: Abstract Test Suite specification".

[3] ISO/IEC 9646-4 (1994): "Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 4: Test realization".

[4] ISO/IEC 9646-5 (1994): "Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 5: Requirements on test laboratories and clients for the conformance assessment process".

[5] ISO/IEC 9646-6 (1994): "Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 6: Protocol profile test specification".

[6] ISO/IEC 9646-7 (1995): "Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 7: Implementation Conformance Statements".

[7] ISO/IEC 9646-3 (1998): "Information technology - Open Systems Interconnection - Conformance testing methodology and framework - Part 3: Tree and Tabular Combined Notation (TTCN)".

[8] ETSI report (1996): "GMM - Global Multimedia Mobility - A Standardization Framework for Multimedia Mobility in the Information Society".

[9] Void.

[10] CCITT Recommendation Q.785 (1991): "ISUP protocol test specification for supplementary services".

[11] ITU-T Recommendation Q.784.1 (1996): "ISUP basic call test specification: Validation and compatibility for ISUP'92 and Q.767 protocols".

[12] ITU-T Recommendation Q.784.2 (1997): "ISUP basic call test specification: Abstract Test Suite for ISUP'92 basic call control procedures".

[13] ITU-T Recommendation Q.784 - Annex A (1993): "TTCN Version of Recommendation Q.784".

[14] Void.

[15] Void.

[16] ETSI TCR-TR 006: "Methods for Testing and Specification (MTS); ETSI and certification in telecommunications; Overview of outstanding issues and some recommendations".

[17] Void.

[18] ETR 303: "Methods for Testing and Specification (MTS); Test Synchronization; Architectural reference; Test Synchronization Protocol 1 (TSP1) specification".

[19] EG 202 107 (V1.1): "Methods for Testing and Specification (MTS); Planning for validation and testing in the standards-making process".

[20] EIF: "Framework Interconnect Agreements Guidelines" Edition 2, April 1997.

[21] ETP: "Framework Interconnection Agreement: Guidelines for Testing" (version 1, April 1998).

[22] EURESCOM P412 Deliverable 3: "Methodology and Tools for ISDN Network Integration and Traffic route Testing - Test specification for ISDN network integration testing - Volume 2: Guidelines for NIT Session Management".

[23] EURESCOM P410 Deliverable 3: "End-to-End service testing for pan-european ATM network - Practical Guidelines for end-to-end test campaigns".

[24] EURESCOM P613 Deliverable 1: "Methods and tools for B-ISDN Network Integration Testing - Specification for B-ISDN NIT: Test Specification for ATM/Frame Relay Interworking".

[25] EURESCOM P613 Deliverable 2: "Methods and tools for B-ISDN Network Integration Testing - Test specification for B-ISDN network integration testing".

[26] EURESCOM P613 Deliverable 3: "Methods and tools for B-ISDN Network Integration Testing - Test Specifications for narrowband services (GSM, ISDN, PSTN)".

[27] EURESCOM P613 Deliverable 5: "Methods and tools for B-ISDN Network Integration Testing - Executive Summary and main findings".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Network Integration Testing (NIT): it denotes the testing activities, test suites, administrative procedures, etc. that are performed and used by an Operator to ensure that the different Network Elements or sub-networks within its own global infrastructure are interoperating correctly and/or to ensure that its infrastructure is interoperating correctly with the infrastructure of an other non-competitive operator which is interconnected on a commercial basis for the global provision of some "global" telecommunication services

Network Interconnection Testing (NIT): it denotes the testing activities, test suites, administrative procedures, etc. that are performed and used by an Operator which must interconnect its networks to the network or equipment of somebody else because of some obligation coming from Regulation

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ASP	Abstract Service Primitive
ATM	Asynchronous Transfer Mode
ATS	Abstract Test Suite
B-ISDN	Broadband-ISDN
CCBS	Completion of Calls to Busy Subscriber
CM	Co-ordination Message
CT	Conformance Testing
DSS1	Digital Subscriber Signalling number 1
EIF	European Interconnection Forum
EtE	End to End
ETP	The European Telecommunications Platform (formerly, EIF)
ETS	Executable Test Suite
FE	Front End
GMM	Global Mobile Mobility
GSM	Global System for Mobile Communications
I/O	Input/Output
ICS	Implementation Conformance Statement
INAP	Intelligent Network Application Part (SS7)
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISUP	ISDN User Part (SS7) (a generic implementation of ISUP)
ISUP-I	ISDN User Part (SS7) international version, as defined by ITU-T Recommendation Q.767
IT	Information Technology
IUT	Implementation Under Test
IWF	InterWorking Functions
IXIT	Implementation eXtra Information for Testing
LAN	Local Area Network
MAP	Mobile Application Part (SS7)
MPTM	Multi Party Test Method
MTP	Message Transfer Part (SS7)
NE	Network Element
N-ISDN	Narrowband-ISDN
NIT	(1) Network Integration Testing
NIT	(2) Network Interconnection Testing
NNI	Network [Element] to Network [Element] Interface
NtN	Node-to-Node
O&M	Operation and Maintenance
OSI	Open System Interconnection
PCO	Point of Control and Observation
PDU	Protocol Data Unit
PICS	Protocol Implementation Conformance Statement
PIXIT	Protocol Implementation eXtra Information for Testing
PLMN	Public Land Mobile Network
POTS	Plain Ordinary Telephone Set
PSTN	Public Switched Telephone Network
PT	[Protocol] Tester
SCCP	Signalling Connection Control Part (SS7)
SS7	Signalling System N. 7
SUT	System Under Test
TCP/IP	Transmission Control Protocol - Internet Protocol
TE	Terminal Equipment
TLC	Telecommunication
TMN	Telecommunication Management Network
TMP	Test Management protocol
TSP1	Test Syncronization Protocol 1
TSP1+	Test Syncronization Protocol 1+

TSP2	Test Syncronization Protocol 2
TTCN	Tree and Tabular Combined Notation
UNI	User Network Interface
VPN	Virtual Private Network
WAN	Wide Area Network

4 New needs in the network testing domain

As a consequence of competition and of network evolution, the Network Operator's customers are being provided with a growing number of diversified services which are offered by networks operated by a single Operator or actually by the integrated or interconnected networks (and/or special equipment) operated by different Operators and/or Service Providers.

All these "networks" will either need to be (strongly) integrated at all layers or just to interconnect with each other at the lower layers, in any case allowing customers with different characteristics to communicate with each other. In some cases, when the two networks are really integrated, also the service provision capabilities might be shared. In both cases, the resulting "global network" (global infrastructure) would probably include different access networks, core transport networks, service networks (for the retrieval/processing of information), different technologies, etc.

Commercial reasons (market) and the pressure of regulators (competition) constitute two basic drivers for integration and/or interconnection of networks.

4.1 Market reasons

Market reasons (traffic increase) constitute one driver for an increase towards networks integration: networks may open their boundaries towards others building a global (end to end) connectivity, which is in the end in the final expectations of the users, and the envisaged traffic increase may generate additional revenues to Operators. For example, ISDN users can nowadays easily communicate with each other and with GSM users. Apart from traffic increase, the large reachability of different customers may become a requisite for further commercial success of Network Operators or Service Providers and may also be or become an obligation coming from Governments or other Regulators.

From the administrative and technical point of view such increased integration means that different pieces of network equipment must be able to interwork at some quality level, ensuring final interoperability to the served customers. Such pieces of equipment are, for example:

a) in operation in different networks;

b) owned by different organizations;

c) operated with different procedures;

d) made by different manufacturers;

e) possibly using different base technologies.

This overall complexity (technical, administrative) requires for effectiveness and efficiency that some *specific* network testing is organized and performed, all such methods, tools and procedures can simply be called "Network Integration Testing".

4.2 Competition

Today's scenario is also changing due to the pressure of Regulation pushing towards the full opening of public networks operated by dominant Operators to others Operators or Service Providers, etc., this time in order to enable or increase competition in the market. Even if in this case such interconnection is more an obligation rather that a commercial choice (at least for the dominant operator), still there is a final need to ensure and determine if "it works", "is secure", "preserves the networks integrity", etc.

Therefore, the deployment of full competition (regulated competition) is another driver for the development of *specific* technical basis in the domain of network testing, let's simply call all such methods, tools, procedures "Network Interconnection Testing".

5 Networks' Integration and Networks' Interconnection

"Network Integration Testing" is the term used in the present document to denote the network related testing activities, test suites, administrative procedures, etc. that are performed and used by an Operator for improved performance of its of Network Elements, and of its own network as a whole.

This Operator, for example, may wish:

- to ensure that the different Network Elements within its own infrastructure are interoperating correctly; or
- that its infrastructure is interoperating correctly with the infrastructure of an other non-competitive operator which is interconnected on a commercial basis for the global provision of some "global" telecommunication services (e.g. Euro-ISDN).

"Network Interconnection Testing" is the term used in the present document to denote the testing activities, test suites, administrative procedures, etc. that are performed and used by an Operator which must interconnect its network to the network or equipment of somebody else because of some obligation coming from Regulation.

Both Operators, for example, may share some interests:

- to assess that the other "to be interconnected" network is not a menace for one another network integrity; and/or
- to assess that the interconnection traffic is well documented (for detailed accounting reasons) or to ensure that a minimum level of quality (of the TLC services) exists at the beginning and is likely to be maintained, etc.

The different types of testing activities just introduced (Integration, Interconnection), which are generated from different motivations, share anyway quite a few components (e.g. terminology, test specifications, tools, etc.) that are needed in order to test and validate if-how Networks and Network Elements perform together.

5.1 Networks Complexity

As already mentioned, today's telecommunication networks are becoming ever more diverse and complex. A single virtual global network is resulting by interconnecting or integrating different sub-networks of different shapes, owners and technologies, which are offering TLC services to the end-users (customers).

Together with Network Elements (NE) supporting the traditional telephone networks (POTS), modern networks comprise NEs with different purposes and features such as, for example, ISDN, mobility management, intelligent services, virtual private networks, broad-band multimedia, IP-based, etc.

In the field of software architectures for telecommunications, software agents and intelligent agents may also play an important role for executing user controlled activities in networks.

The distinction between mobile and fixed network also tends to decrease, through convergent solutions.

All the network solutions mentioned above cannot be considered independently of O&M systems that represent some sort of "upper" network layer, or plane, interacting with the controlled Network Elements. Thus, the influence of Operation Systems (management networks, TMNs) on the managed Network Elements is also relevant for the "global" network behaviours.

The distinction between private and public networks is becoming more undefined with the introduction of Virtual Private Networks (VPNs) into the public environment. The set of players involved in the telecommunication scenario is also rather complex and fast-moving, including fixed network TLC operators (providers of PSTN/ISDN), access network providers, cellular network providers, Internet access and Service Providers, intelligent networks services providers, etc. The possible development trends and scenarios of TLC network and services include, among others, many aspects and components [8], such as the following.

5.1.1 Customization

The capability of the network to adapt the provided service features on the basis of the user needs has been already introduced in many intelligent networks and management networks. The final goal is to allow users to control the characteristics of the subscribed services. An example of customization in modern networks is the capability for a B-ISDN user to negotiate the service quality (bandwidth and bit error rate) with the network (according to his current needs).

5.1.2 Mobility

This concept includes different aspects, as described in [8], from which figure 1 has been taken.

a) Terminal mobility: the ability of a terminal to access telecommunication services from different locations and while in motion, and the capability of the network to identify and locate that terminal or the associated user.

b) Personal mobility: the ability of a user to access telecommunication services at any terminal on the basis of a personal telecommunication identifier, and the capability of the network to provide those services according to the user's service profile.

c) Service profile portability: service profile is the capability of the network to provide a particular set of service features from any access according to the user's demands. Service profile portability is the capability for a subscriber to have his service profile available on networks other than his "home network".

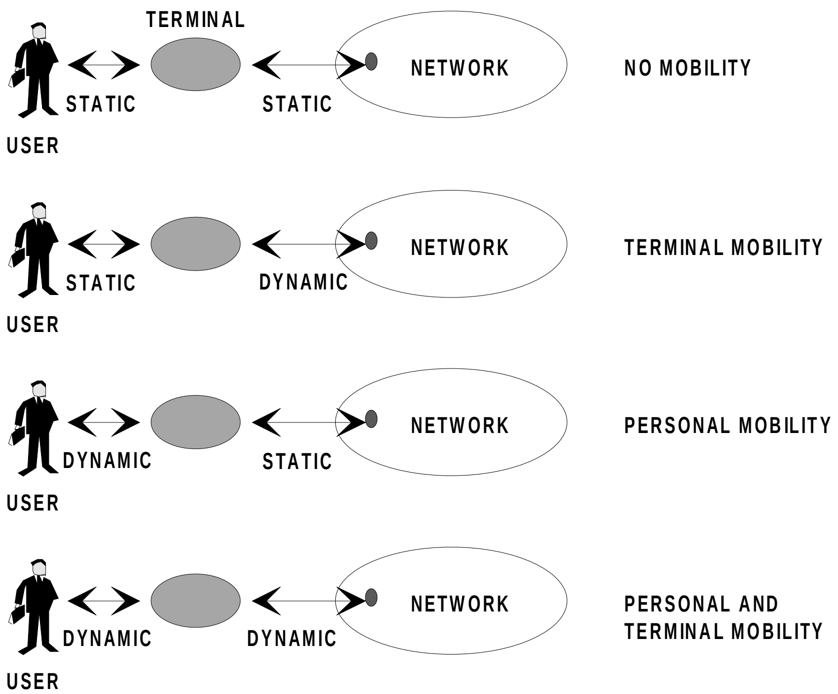

Figure 1: Different aspects of mobility

5.1.3 Multimedia

The introduction of non-voice information in accordance with human perception (sound, picture, video => Multimedia) has been made available by the deployment of N-ISDN and the gradual introduction of broadband capabilities. Also the extremely rapid growth of Internet has a significant influence on the introduction of multimedia services. Besides, its differences from traditional telecommunication networks, e.g. with reference to billing, architecture and technology, is changing the user approach to such services.

The rapid introduction of Cable TV networks and network broadcast capabilities proves the shift from separate industries for Communications, IT and Broadcasting, to convergence through the integration of services and operations.

5.1.4 Internationalization

The interconnection among network users involves more and more often networks managed/exploited by Service Providers of different nationalities, and under different normative regimes.

5.2 Deregulation and Competition

The shift from monopoly supply to an open competitive market in services and equipment causes an increase in the number of deregulated areas and an obligation to open and interconnect public networks in every country to other Network Operators and to network Service Providers.

This change reached a major point in Europe at the complete deregulation of telecommunication infrastructures within the European Union, January 1998.

For the specific aspect of interconnection, a framework approach to such testing (**Network Interconnection Testing**) has actually been defined [21] by the ETP forum (Formerly EIF) in the framework of generic studies on Interconnection [20]. It is currently being further investigated: a new version of [21] is actually planned by ETP within 1999, covering also the aspects of testing of Number Portability. Other bodies may also be sharing interest on this subject.

Considering the implications on testing, as we said already, the NIT (**Network Integration Testing**) methodology can be "ported" and applied, possibly with changes, to the testing of interconnected (or to-be-interconnected) networks in any given Country (according to local provisions of the National Regulations, and/or following the specific Interconnect Agreements between Operators and Service Providers active in that Country).

Actually the contexts of Network Integration and Network Interconnection share similarities but are not coincident: in the latter case (Interconnection of Networks operated by competing players) all the players would not always share the same goals and business objectives. There may be conflicting interests. On the contrary the NIT (Network Integration) methodology must be based on full co-operation among the concerned network players.

But at least a tiny part of the Network Integration Testing (NIT) methodology (e.g. terminology, concepts) and some relevant subsets of the concrete "testing products and results" can be immediately applied/re-used, or are easily adaptable to the case of interconnection testing. For example:

a) the SS7 Node-to-Node test suites (e.g. the ISUP, MTP, SCCP NtN Test Suites, such as those released so far by EURESCOM and other bodies) appear to be immediately re-usable for interconnection;

b) the End-to-End Test Suites may also be easily re-used. For example, sub-sets (or super-sets) of ISDN or ATM EtE Test Suites (such as those released by EURESCOM or the ATM forum) could be adopted/adapted, if there is a wish to test end to end service quality.

c) Some other "technical domains" share many commonalties. They include:

    1) routing (= the end to end reachability of customers, the establishment of TLC connections);

    2) traffic documentation and traffic measures (important for the purposes of monitoring the overall network traffic performance);

    3) call documentation (important for the invoicing to each other of traffic terminated or delivered following specific agreements and solutions, such as carrier selection, number portability, etc.).

5.3 Requirements and goals of new testing methodologies (NIT)

5.3.1 Requirements

Potential interworking and interoperability problems could arise within a global infrastructure (or even among the NEs of a single network) when some changes are introduced somewhere in one network. A case could be a new set of [supplementary] services that enters into operation, or a new version of a protocol (e.g. ISUP, DSS1, MAP, INAP) when it is deployed.

Actually, just changes to the NE data (configurations) could affect the global service and performance.

To prevent or limit the occurrence of potential impacts, the global network behaviours should be testable/observable in principle as much and as deep as possible:

- a priori, before the deployment of changes; and/or
- a posteriori, during normal operation (it should be at least easily and quickly monitorable).

The testing methodology should therefore have the following characteristics:

1) **Strict requirements:**

   a) ability to test and monitor the network(s) integration by handling the network(s) as a whole;

   b) ability to test networks geographically distributed, involving different operators and testing laboratories - strict requirement if the system under test is, as usual, geographically distributed;

   c) definition of "not-only-domestic" approaches and techniques - strict requirement if the methodology is to be used by more than one Network Operator or testing laboratory;

   d) cost-effective, rapid and cheap testing of services, to reduce time-to-market and/or to fix quickly any severe bugs;

   e) non-intrusive, not breaking network integrity or network functionality and performance.

2) **Opportune requirements:**

   a) ability to test heterogeneous chains of systems such as switching, management, transmission and user equipment - requirement for coverage, effectiveness and relevance;

   b) development of tests based on independent units referring to a single interface ("test components") - requirement for cost reduction and reuse of testing software;

   c) Procedures for the resolution of problems and bugs. In case of unexpected problems, effective and reliable technical methods and managerial procedures/processes to investigate the reasons and localization of the possible failures would also be very useful. However, the complete localization of problems, i.e.:

      1) "where" the problem is generated (which Network or Network Element exactly generates the problem);

      2) "where" the problem creates impacts (the two "where", being possibly different); and

      3) the attribution of a degree of "severity" and/or "urgency to fix" the problem.

Procedures for problem resolution can probably only be a set of optional and desirable features, due to high costs of such investigations and also because such features may have implications which are "*non-only-technical*".

5.3.2 Goals

The main purpose of NIT is to evaluate the overall behaviour of different networks and to increase the probability that the network services are supplied to the customers in a correct and reliable way.

5.3.2.1 Strategic objectives

Two are the major strategic objectives:

a) to allow Network Operators to verify that their customers can be provided with the subscribed services when connected with users of other networks;

b) to test the complex "global network" in a more direct and cost-effective way, by evaluating the behaviours of many Network Elements at the same time.

The NIT methodology aims at avoiding useless multiplication of efforts in the achievement of its objectives and therefore includes general operational guidelines and proformas for the players (in addition to the technical references such as the NIT ATSs). Such guidelines should be easily acceptable by different Organizations, because always designed keeping in mind the need of preserving confidentiality; normally no unnecessary information is asked to be disclosed if it is not strictly needed to perform the NIT tests.

5.3.2.2 Technical objectives

From the technical point of view, the main objective of NIT is to verify the actual service provision to users of different connected networks, checking that the complex interworking between interconnected networks do not cause problems.

The localization of the causes of any possible detected problem is just a (useful) option, since it may be very expensive in general to localize a failure. In fact, when the complexity of the network under test increases, it is almost impossible (or very difficult) to determine "where" the testing call is being routed, because the actual path will depend on the traffic " global state" of the real operational network. Only when it is possible to force some specific routing, e.g. by using dummy (unused) country codes along the path of NIT calls, the location of problems may become possible.

Conformance of each network component to the relevant specifications and standards is considered a prerequisite, implicit or explicit. In other words, NIT can be executed independent whether Conformance Testing (CT) has actually been performed ahead of time (by the Network Operator, by its Supplier(s), or by Third Parties).

It is implicitly or explicitly assumed that the different networks components are conformant to relevant standards, which are identified by NIT (using a mechanism derived from the concept of the ICS proformas used by CT; typically, NIT ICS have with dual entries to be filled in, independently, by the two parties involved in an "official" NIT testing session).

6 What is actually testable with NIT?

The object of NIT is a network, or a part of it, made up by interconnecting two or more NEs. Heterogeneity is not a requirement for NIT, but the methodology is applicable to networks characterized by differences, like:

a) NEs released from different manufacturers;

b) different releases of a given NE;

c) different kinds of services (e.g. mobility, intelligent network);

d) different technologies;

e) different operators.

Interworking, intended as the interaction between protocol entities which includes the conversion of physical states and the mapping of protocols, is actually already considered by Conformance Testing when the Implementation Under Test (IUT) is an open relay system.

NIT however does not focus on the conformity of the InterWorking Function(s) (IWF) in a single NE, but considers the global interaction resulting from the IWFs of as many different NEs as those actually encountered by a typical call crossing a real network.

6.1 How is NIT used

Considering now some specific current technical domains and technologies, NIT has already been used in many companies in the areas of:

a) ISDN and Mobile services (e.g. basic speech/data call and supplementary services);

b) Broadband ISDN/ATM;

c) Intelligent Network Applications (e.g. INAP);

d) for the interconnection of Signalling Networks (e.g. for the provision of advanced services such as CCBS).

In general, the object of the NIT methodology is the set of two networks connected directly (or possibly through a third transit network, or a sequence of transit networks), as described in figures 2 and 3.

The networks are observed and controlled through some interfaces (user-network or network-network) which are related to what in the ISO/IEC 9646 terminology and in [7] are called PCOs (Point of Control and Observation). There are at least two PCOs for the control and observation at the external borders (minimum mandatory configuration) and, as an optional feature, one or more additional PCOs only for observation (i.e. in order to monitor the internal network behaviour).

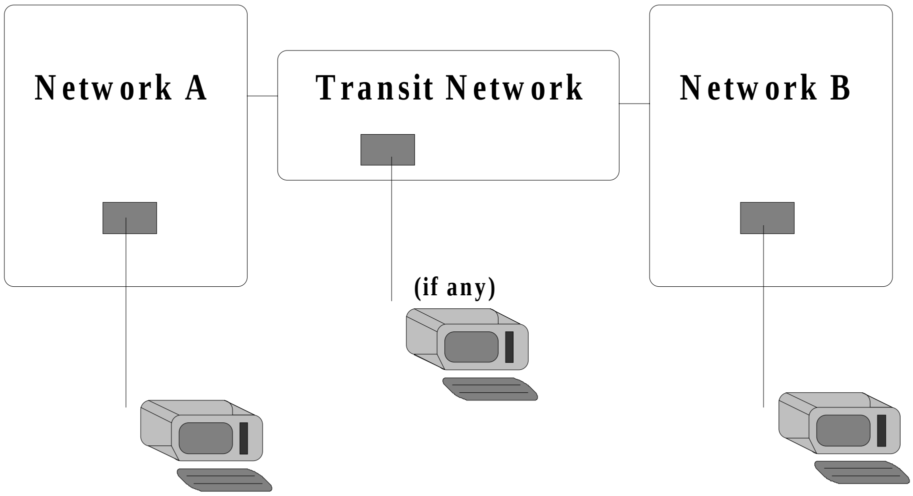

Figure 2: Generic configuration for a NIT testing session, including distributed Testers

The actual number and location of the PCOs depends on the characteristics of the networks and on the functionalities to be tested. The physical testers shown in figure 2 are logically located at such Points of Control and Observation. Such "points", in real life testing, may actually be close to each other or may possibly be very far: actually NIT may be applied to geographically distributed testing, as it is in the case, for example, of ISDN international NIT testing among 2 International Gateways placed in 2 different Counties.

The monitoring point indicated in figure 2 is optional. The two other PCOs must always exist; as a particular case, the functions of one tester located in one of such PCOs might actually be replaced by equivalent actions performed by the corresponding node. Some arrangements made on the routing tables and looping of physical trunks on that node could be able to generate back the expected PDUs (acting more or less as a sort of "lower tester", in terms of CT terminology) but making NIT testing more easy, from an organizational point of view.

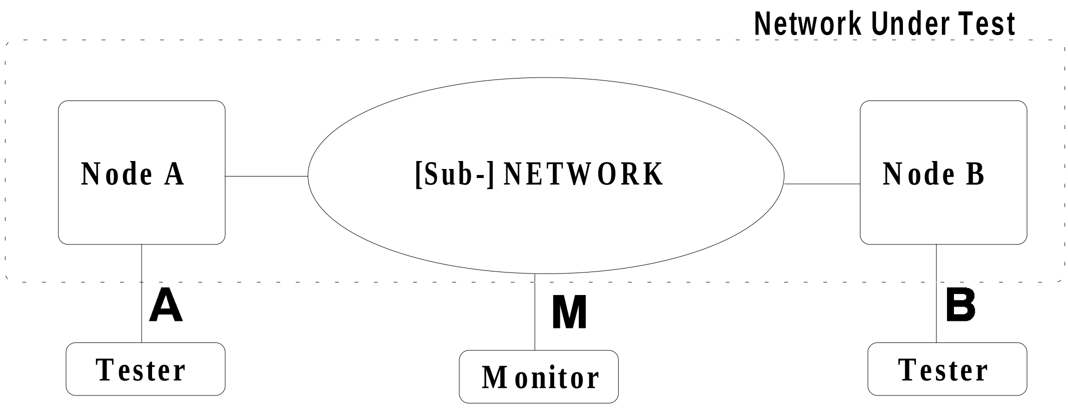

Figure 3: Example of a System Under Test (SUT), from the point of view of NIT

The "NIT IUT" is composed of all the parts that contribute to perform the expected network functionality, i.e. connection and transport of data and signals between the external gates (A, B [, M]):

- protocols that manage the external entities connected to the SUT (access protocols in the case of End-to-End testing, network protocols (e.g. ISUP) in the case of Node-to-Node);

- each network component or function involved in a call between the A-side and the B-side (e.g. all call-control functions in all crossed NEs).

NIT should be conceived in order to allow it to be executed in two different operational situations:

1) in a controlled situation, i.e. in a local or distributed test plant, or interconnected test plants, before the new functions and services are deployed into the real Network Elements;

2) in a real situation, when the functions and services have already been deployed in the real Network Elements, which are therefore in an operational state. In this situation the Test Suite and the related procedures should be designed so as not to interfere and break the "normal" network behaviour.

Finally, depending on which interfaces the testers do use to access the network, there are two different testing configurations: End to End (EtE) and Node-to-node (NtN).

In End to End, the network is tested as it is seen from the user's Terminal Equipment (TE), i.e. taking the user-network interfaces as PCOs. For example, A = an ISDN Basic or Primary Access protocol; B = an ISDN Basic or Primary Access protocol, with reference to figure 3.

In Node-to-node, the network is tested as it is seen from the other internal network components or sub-networks. The PCOs are the external network-network interfaces. In figure 3, M is a generic monitor point (PCO) that is used to check the internal behaviour of the network. For example, A = B = a national version of the ISUP protocol, M = ISUP-I protocol.

6.2 End-to-End and Node-to-node testing

As already said, an End-to-End testing means to test the network as seen at the user accesses while a Node-to-Node testing means to test the network as seen from the network trunks. Therefore EtE is concerned only with the external behaviour of the network, while in NtN also the internal behaviour is object of testing and observation.

This distinction within NIT should allow to reach flexibility and a high level of confidence in the network correct behaviour since the network itself can be tested from the point of view of the network protocols (NNI), as well as from the point of view of the access protocols (UNI).

A possible application order of NIT Suites might be:

1) Node-to-node testing (e.g. for trunk operators, as in order to test transport functions), to check the core network;

2) End-to-end testing, to check in the users' viewpoint.

Figures 4 and 5 show respectively examples of End-to-End and Node-to-Node testing configurations.

Note that the latter allows the performance of "NNI Compatibility Testing", for example, to test that two adjacent SS7 Signalling Points can exchange ISUP messages according to the relevant ITU-T and CCITT Recommendations [10], [11], [12], [13].

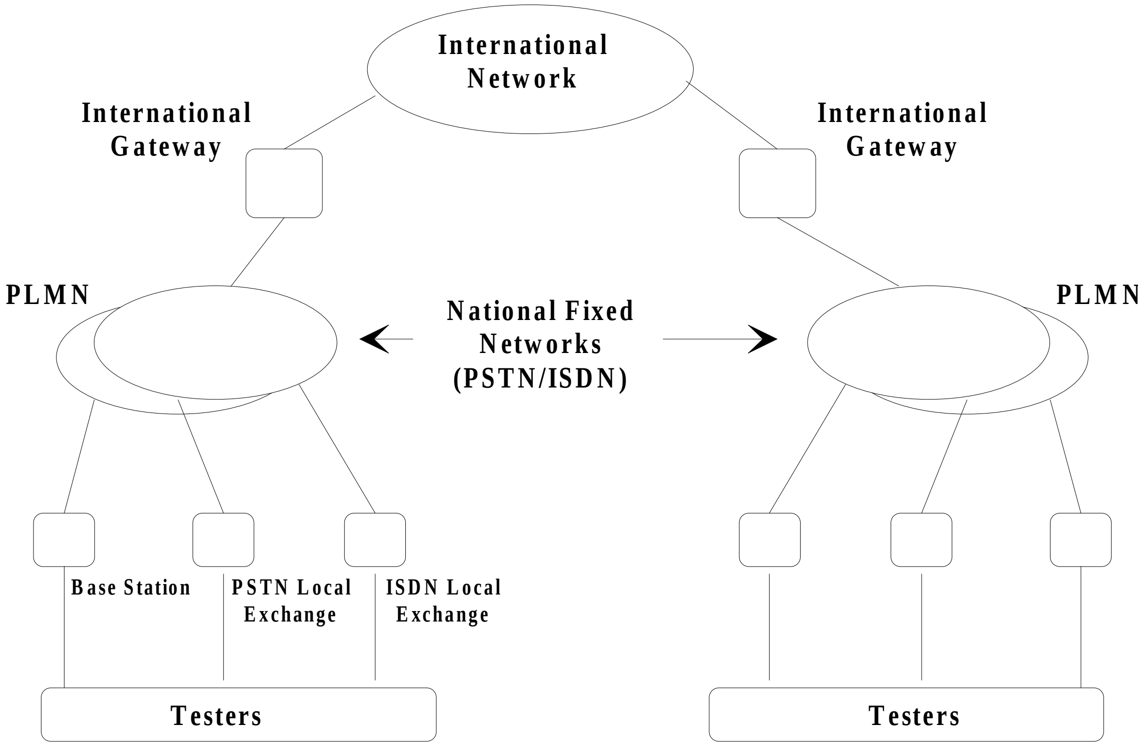

Figure 4: An example of End to End testing Configuration

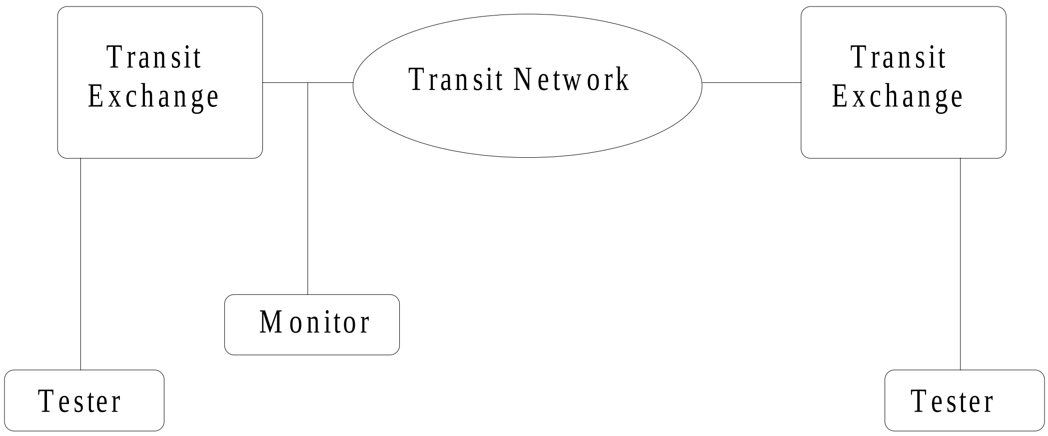

Figure 5: An example of Node-to-Node testing configuration

6.3 Conformance Testing versus Network Integration Testing

6.3.1 A traditional solution to Network testing: Conformance Testing

Conformance Testing is specified in ISO/IEC 9646 [1] to [7] which is a multi-part standard defining the general principles of the methodology, the test suite specification, the recommended notation for the abstract test suite definition, the guidelines for test realization, the requirements on the test laboratories and the Implementation Conformance Statement (ICS).

In this context, an important goal of ISO/IEC 9646 [1] to [7] was to guarantee the formal quality of the testing process and the comparability of results (so that the executions of conformance assessment processes on the same implementation, in different test environments, lead to the same results).

Conformance Testing can also be voluntarily and informally used for some Network Testing, for example when a new feature or functionality of a Network Element, or a new version of it, is about to be deployed.

The goal of this first network side testing step is to verify that an implementation of the new network functionality conforms to the relevant technical specification(s). This step would allow to introduce into the networks only implementations that have been proved to be conforming to standards.

One purpose of Conformance Testing, when applied to the testing of NEs, is to increase the probability that different such Network Elements, Relay Systems, etc. will be able to inter-work at the appropriate network protocol level (e.g. MTP, SCCP, ISUP, etc.). This is a considered a needed (not sufficient) requisite for the end to end interoperability of services as seen and exploited by the end user (e.g. basic telephony, supplementary services, fax G4, etc.).

6.3.2 The NIT testing methodology

Despite it is also usable by Network Operators for testing their NEs and the services they offer, the CT methodology is probably more directly related to the core business of the Network Elements and Terminal Equipment Manufacturers and Suppliers. It is also relevant to Regulators.

For Network Operators it is particularly important to use a specific, cost-effective, overall testing methodology, assuring an optimal time-to-market for each new service to be deployed. The NIT methodology is in particular relevant from the point of view and core business of Network Operators. It is also relevant to the Users and to the Regulators.

It has already been shown that NIT does not have strong requirements to guarantee the comparability of results obtained in different contexts, but focuses only on demonstrating the correctness and reliability of services in any given case (different behaviour might be considered correct and acceptable, in different contexts). It can therefore be seen as cost-effective, also because "it tests" many Network Elements at the same time.

Table 1 is an attempt to summarize in a schematic way the differences between the Conformance Testing and Network Integration Testing. It may be worth noting that NIT does not necessarily replace CT. CT may remain a first logic step to be conducted (possibly performed by the manufacturers themselves, to demonstrate the quality of the products they sell).

Table 1: Comparison between Conformance Testing and Network Integration Testing

	Conformance Testing	**Network Integration Testing**
Goals	To verify that a protocol implementation conforms to the relevant protocol and profile specifications ⇒ **CONFORMANCE**	To verify that a complex network is able to provide user with services in a correct, homogeneous and reliable way ⇒ **SERVICE, FUNCTIONALITY**
Object	The implementation of an OSI Protocol Specification in a Network Element	A network, or part of it, made up by joining two or more Network Elements
Process phases	1) specification of an ATS, ICS and IXIT 2) realization of means of testing 3) conformance assessment process (or second party testing)	1) specification of an ATS, ICS and IXIT 2) agreement between different Network Operators 3) realization of independent means of testing (one for each test laboratory) and of the TCPs 4) Result collection
Type of Test	**Local or dual** 1) Basic interconnection tests 2) Capability tests 3) Valid behaviour tests 4) Inopportune behaviour tests 5) Invalid behaviour tests	**Dual only** 1) Basic interconnection tests 2) Valid behaviour tests 3) Connectivity tests 4) Stability and performance tests
Users of the methodology	Manufacturers (to guarantee that their products conform the national and international protocol and profile specification) and Network Operators (for the same reason)	Network Operators (for guarantee their customers that the network is able to provide the subscribed services in a correct and reliable way)

6.4 Some open issues of the NIT methodology

The NIT methodology is rather new and some open issues which deserve further study can be pointed out.

6.4.1 Localization

One of them is about the need for efficient and reliable methods and procedures for investigating the reasons and localization of possible incorrect behaviours. This is a critical point especially when the network under test is "very complex".

The first step would be to identify which Operator generated the incorrect behaviour. This may be a quite complex point if the "global network" under test involves several Operators. For example, this could be the case of:

- a mobile customer of a mobile Operator A;
- which is roaming abroad, and there served by a mobile Operator B;
- if that roaming user calls a customer of fixed network Operator C.

The second step could be to exactly identify which particular NE was wrong. This 2nd process could actually involve only the "guilty" Operator, so becoming not so relevant in the NIT philosophy.

6.4.2 Optimization

Another issue relates to balancing between detailed analyses and eavy development efforts and the need of avoiding duplicating efforts. For example, a network fault that emerged by using and End to End Test Suite could be investigated in detail by executing a corresponding Node-to-Node Test Suite (with equivalent Test Purposes). This would be costly but would help to more precisely identify whether the problem is in charge of a transit network or stays entirely on the access network(s).

The situation could be the one described in figure 6 where a subset of tests of the two Test Suites verifies the same behaviours, obviously in different ways, and the rest of the Test Cases are specific for the Test Suite.

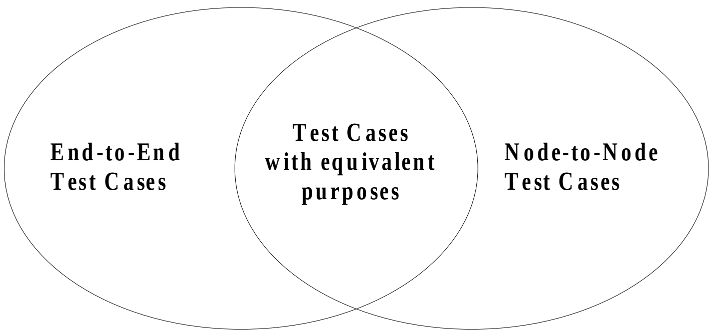

Figure 6: possible correspondence between End-to-End and Node-to-Node Test Cases

A view could be that only one type of testing should be developed/executed because of the need to save time and resources. Actually it was considered useful within the EURESCOM P613 [24] to [27] project to develop both types and maintain relations and correspondences between the End-to-End and Node-to-Node Test Suites which were under development under that project.

6.4.3 Costs and availability of NIT ETS on the market place

The number of NIT ETS available on commercial testing platforms (on the market place) is growing consistently every day but, due to their intrinsic complexity and to the reduced market, the prices of such products, when commercially available, are in general not cheap.

6.5 Some results from the NIT methodology

One of the more prolific originators of NIT Test Suites is EURESCOM.

In 1992 the EURESCOM P104 project on ISDN testing started introducing explicitly the concept of end-to-end testing, in which the tested object is not an implementation of a stack of protocols in a given system from a single vendor, but is the functional behaviour of a whole network. The testing was to be performed stimulating one access point and checking the reaction of the network at other access points, simulating a functional procedure, as a basic call, between a pair of ISDN users. Some testing of supplementary services was also provided.

In the period 1994-1996, the EURESCOM P412 [22] project, building on the P104 experience, further developed the concept and started applying systematically the new methodology to the Euro-ISDN network made up by interconnecting the national networks of different fixed Operators. One goal of the project was also to explicitly define such a methodology, that was presented with the name of "Network Integration Testing". In the same timeframe the EURESCOM P410 [23] project covered with similar aims the testing of ATM-based networks. The two projects worked in liaison.

Between 1996 and 1999 the EURESCOM project P613 [27] developed NIT test suites, spanning in the areas of narrow-band and broad-band NIT testing. On the broad-band side, P613 extended and further enhanced the P410 NIT results, e.g. to cover in greater detail the broad-band ISDN EtE testing and IP over ATM [24], [25]. On the narrow-band side, new narrowband NIT test suites added greater coverage to the interoperability of services delivered by fixed (ISDN or PSTN) and/or mobile (GSM) interconnected networks [26].

It may be worth mentioning that all the test suites released by the P410, P412 and P613 projects have undergone with success different validation steps before the termination of the related projects and before being placed in the public domain. Validation had been planned since the beginning. In addition to the EURESCOM references provided in the References clause of the present document, the Bibliography clause provides contact information to learn more on such EURESCOM results.

Most of the mentioned EURESCOM projects on NIT released publicly available ATSs of NIT type; most of them are in concurrent TTCN notation, and can be downloaded by interested parties, without restrictions or costs, in different technical formats (including machine processable) from the EURESCOM servers (http://www.eurescom.de/).

In addition to those released by EURESCOM, other NIT Test Suites have been produced or are being produced by other fora, such as the ATM forum.

7 Conclusions

In the present document, the general concepts of the NIT methodology have been described and a discussion of NIT when compared to the Conformance Testing has been developed. NIT provides a fast and simple method to test interconnected networks.

NIT was first defined within EURESCOM to ensure that interconnected networks operated by Operators working on a pre-competitive basis (or actually not competing , because covering geographically distinct markets) would interoperate correctly, providing the expected level of service to the respective customers. Such NIT testing is typically performed among pairs of networks, with a fully co-operative approach among the [two] operators involved, following [bilateral] commercial agreements.

The NIT test suites may also be suited or adapted for Network Interconnection Testing purposes, i.e. when networks operated by competing players have to interconnect to each other in any given country, following Regulation and the signature of specific Interconnect Agreements among such players. Moreover, the NIT test suites could be considered by national or super-national Regulating Authorities as future technical bases for regulating (if/when appropriate) any Interconnection Testing matters resulting from the opening and Interconnection of networks.

In addition to the original "multi-player" role, the NIT test suites can also be easily adapted to ensure interoperability testing within a network infrastructure operated by a single Network Operator. In this case, NIT would ensure that Operator that the possibly different network technologies (i.e. fixed, mobile, broad-band, etc.) and/or multi-vendor sub-systems encompassed within its network can actually interwork correctly providing the expected services to the end users (i.e. are interoperable).

From the technical point of view, the test suites that are produced according to the NIT concept are basically divided into two categories: End to End Test Suites and Node-to-Node. The former cover functional testing from the point of view of the customers which have accesses to the network(s) (e.g. a basic ISDN access, a POTS access, etc.), whilst the latter cover functional testing from within the network itself (e.g. from the point of view of the network trunks).

The NIT methodology overcomes some limitations of Conformance Testing (which anyway still has a role, in particular from the point of view of manufacturers) as it is immediately focused to the final objective "achieving/exploiting Service Interoperability" which is extremely relevant to Network Operators, Users, Regulators. In particular, NIT allows Network Operators to ensure their customers that the subscribed services are provided in an homogeneous and reliable way, when they are connected to users of other networks.

The functionality under NIT testing may be defined case by case. The definition of the type of test may depend on the characteristics of the network or of the service functionality of interest. The NIT methodology is particularly useful for testing the interoperability of services offered by heterogeneous networks. In this respects NIT represents a cost-effective testing methodology which is appropriate for the high levels of complexity and integration in the current and future telecommunication networks.

Annex A: Style principles for designing NIT ATSs

A.1 General principles

Any new functionality should be tested at some extent before its introduction into a NE in order to verify that it complies with the relevant protocol specification. This is the first step of the testing and is called Conformance Testing. Its methodology and framework are defined in the ISO/IEC 9646 1 to 7 standards [1] to [7].

Conformance testing (conformance to standards) detects errors rather but cannot demonstrate their absence. Thus conformance to a test suite alone cannot guarantee interworking. What it does do is give confidence that an implementation has the required capabilities and that its behaviour conforms consistently in representative instances of communication.

Moreover, the technical specifications, in some instances, may induce interworking problems. Actually, the technical specification should be clear and complete but in the same time allow competition and "product" differentiation. This double aspect may bring about some interworking problems, due to a set of shortcomings as the following:

a) presence of too many options;

b) unnecessary complexity;

c) the correct behaviour of the system under test is not described for all the possible states and for all the event occurrences;

d) lack of completeness (technical standards may described **what** the system under test should do but not **how** it should do it).

Therefore it comes out the need for a testing methodology **focused on the functionality** supplied to the "users".

In this context, the "users" may be:

a) other Network Operators, if the system under test is a transport network, a backbone network, as in the case of node-to-node testing configuration, described hereafter;

b) the end users, if the system under test includes access networks or sub-networks, as in the case of end-to-end testing configuration, described hereafter.

From the technical point of view, NIT is the set of all the checks necessary in order to verify that a given network works as it is expected, and to verify the compatibility of the single network components.

A.1.1 The testing process

The NIT testing process may be unfolded into five logic sub-processes:

a) realization of a test specification for the testing a network related functionality;

b) definition of a related test execution architecture;

c) definition of guidelines for test execution;

d) test execution(s);

e) final reporting.

In most cases, a given NIT specification (steps a, b, c) can be re-used many times for NIT executions (steps d, e).

A.1.2 The Abstract Test Suite (ATS) definition

NIT test specifications that are designed to be dedicated to a specific network solution or are applicable only to a proprietary solution are not in the scope of the present document. We concentrate here only on "abstract" test specification.

Abstract tests should cover not only the conformance requirements from a protocol specification but also the associated network behaviours (functions) depending on it. Therefore, in most cases, in addition to protocol testing, some associated call control functions should also be checked, e.g. that the transfer of speech or data takes place correctly, or that specific O&M messages are generated on a maintenance console, etc. If it is find difficult, even using concurrent TTCN, to express formally all such interactions at so many PCOs, then a current practice is to indicate such additional (but fundamental) aspects using comments, or other informal ways. In NIT specifications, if/when a choice must be made between effectiveness and elegance, the first usually takes precedence.

The Abstract Test Suite should be defined in term of Test Components, one for each PCO, in order to allow independent implementations to operate together. The Abstract Test Suite must also define the Test Co-ordination Procedure (TCP) for the test execution [18] and DES/MTS-00051 (see bibliography).

In the NIT context, the Concurrent version of TTCN [7] may be considered the ideal solution for writing most ATSs, when there is a wish or need to use a detailed and well structured notation. ETSI published a new version of TCCN [3] which can be used as a good reference also for designing good NIT ATSs.

In some other cases NIT tests cases may be produced in an informal style, which limit themselves to descriptions in natural language, drawings, etc., and/or are just groupings of test purposes (informal, but yet structured testing).

Whether or nor TTCN should or should not be used it is a "case by case" decision. The pros and cons exercise should normally consider: the intended users, the time to market, the costs, the available skills, the issue of maintenance of test specifications, etc. As far as ETSI is concerned, such policy aspects, including validation of the testing specifications, have been outlined in [16] and [19].

Following the framework of Conformance Testing, the NIT methodology distinguishes conceptually four types of tests:

a) basic interconnection tests (preliminary tests for verifying that some connectivity exists, and that the overall testing machinery and network configurations are OK);

b) valid behaviour tests, which should emulate behaviours coming from the possible user procedures and, if/when applicable, some O&M functions originated by O&M staff;

c) connectivity tests, which should evaluate the bearer connection (e.g. Bit Error Rates and other measures);

d) stability and performance tests, which should check the stability of connections and other aspects which are relevant to the final quality of a service.

But the definition of "Test Purpose" is different from that of Conformance Testing . CT states that a test purpose should be a (omissis)… *description of a narrowly defined objective of testing, focusing on a single conformance requirement as specified in the appropriate OSI specification (e.g. verifying the support of a specific value of a specific parameter*).

In the NIT context, since the base standards contain no explicit requirement for NIT testing, the Test Purposes are usually generated as a result of an analysis of the base standards (may be many) and the related ICS. This analysis, compared with the case of Conformance Testing, is actually rather subjective and based on the telecommunication experience of the test specifiers.

While in Conformance Testing the "states" of the IUT are easy to check, in the NIT context there is quite a number of "states" in the network under test. So, it is up to the test specifiers to choose the most important and representative "network situations", configurations and functionalities of interest.

In any case all NIT tests must have a "dual" (end to end) significance (an event that is just "closed locally" is not a candidate for generating a NIT test case, e.g., a local timer expiry, or the DSS1 actions following the receipt of a wrong SETUP that requires the call attempt be immediately terminated at the UNI interface).

In Conformance Testing the test dynamic behaviour has the following structure, as described in figure A.1:

a) **a test preamble**, used to drive the IUT into the appropriate state;

b) **a test body**, used to check the narrowly defined objective of testing (e.g. to ensure that the IUT is able to react correctly to a specific stimulus). Usually the final state of the IUT is checked;

c) **a test postamble**, used to drive the IUT into the initial steady state.

In NIT methodology the test structure remains the same, but the object of the test body is normally a complete functional procedure like a call, a supplementary service invocation or a simple transfer of a parameter from user to user.

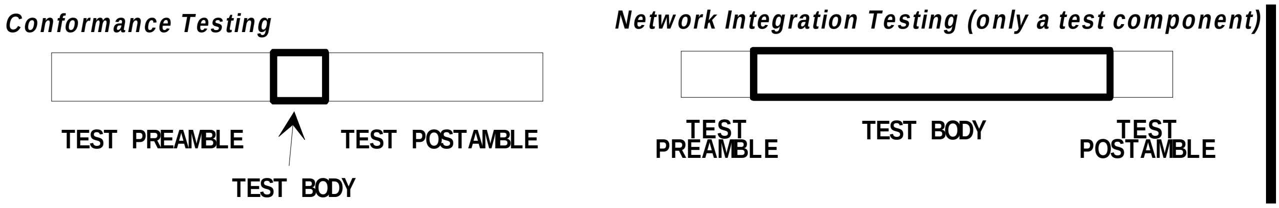

Figure A.1: The Test Case Dynamic Behaviour structure in testing methodologies

Also the edge between the test pre/postamble and the test body is not so sharp. For example, a test case regarding an ISDN basic call may be defined in the following three different ways:

1) *"Ensure that a speech basic call is performed correctly"* (each part of the call procedure is under test - the pre/postamble are absent).

2) *"Ensure that the call establishment procedure with speech capability is performed correctly"* (there are only the test body and the postamble (with the clearing procedure) - another test will check the call clearing procedure).

3) *"Ensure that the speech capability information element is transported transparently through the network"* (the object of the test is only the content of a specific message - only test body, with the transfer of the message, and a postamble for the rest of the call).

A.1.3 The test execution architecture

In the NIT context, the testing system is "by definition" of a distributed nature. It should have the possibility to adapt to various network configurations and implementations. This means it should have a modular and flexible architecture in order to be able to easily integrate other commercial testing [sub-]systems, if needed.

An ideal testing system reference architecture and configuration is shown in figure A.2. We have various groups of tester (PTs, located in general in different places, far from each other). Each PT is controlled by a "Front End " (FE) that must be able to communicate with a "System Supervisor" by mean of a standardized high-level test synchronization protocol (e.g., TSP1, or TSP1+) to transport the test co-ordination messages associate to test co-ordination procedures. The necessity of a standard synchronization protocol derives maily by the need to virtualize different commercial testing equipment, without being forced to use many different proprietary command languages in parallel. Each FE can control various PT that are in general close to it, in general belong to the same Company. Therefore the protocol between FE and the controlled PTs (belonging to the TSP2 set of protocols) is likely to be proprietary and maintained by the testing equipment supplier (together with the rest of the PT, and including the standard TSP1/TSP1+ "upper" interface.

TSP1 will probably use the services of one or more lower layer transport protocols in order to carry the information between SS and each FE. The choice of the actual transport protocol(s) to be used in the lower layers is open and may vary from case to case (e.g. TCP/IP, X.25, Circuit Switched Digital Connections, etc.).

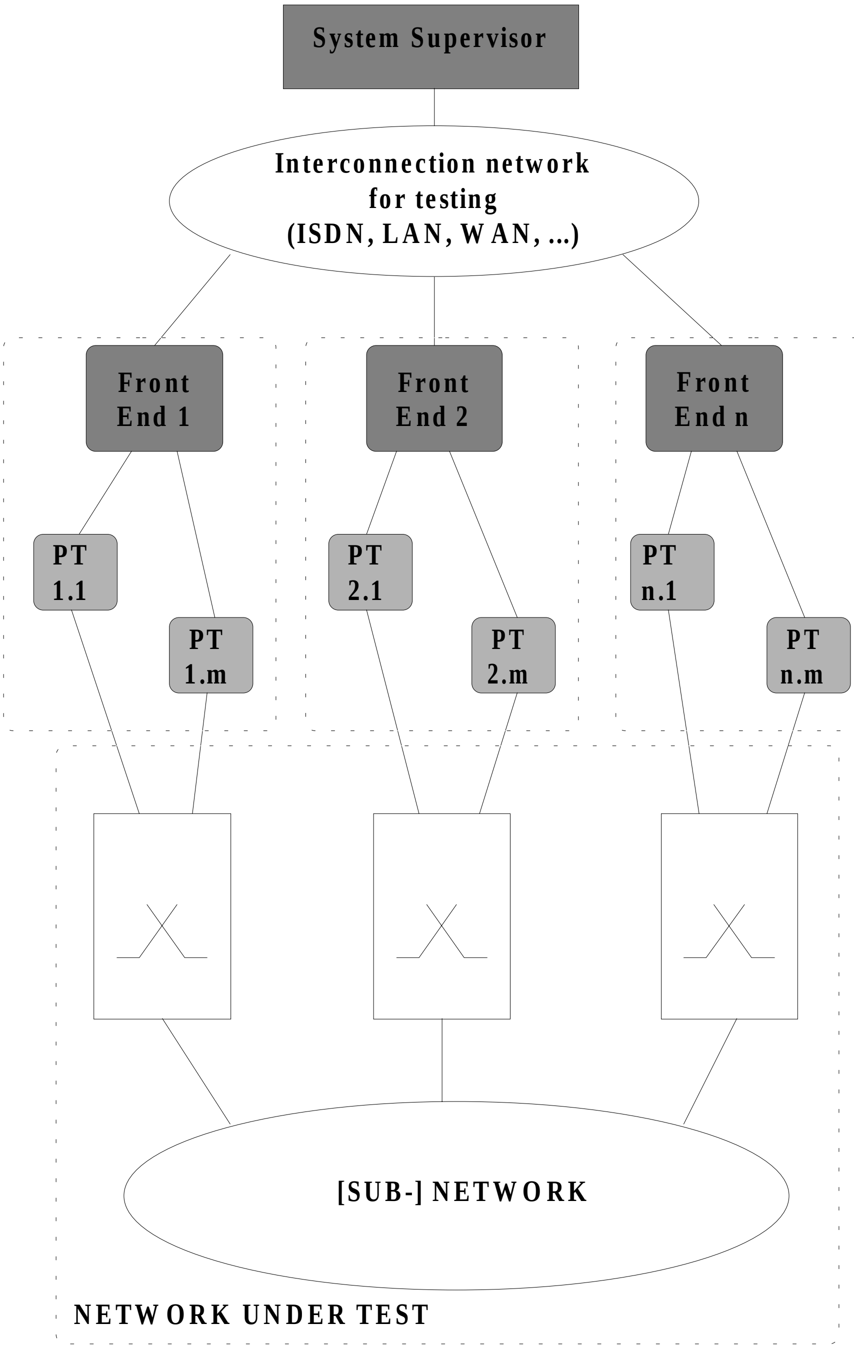

Figure A.2: Network Integration Testing Architecture

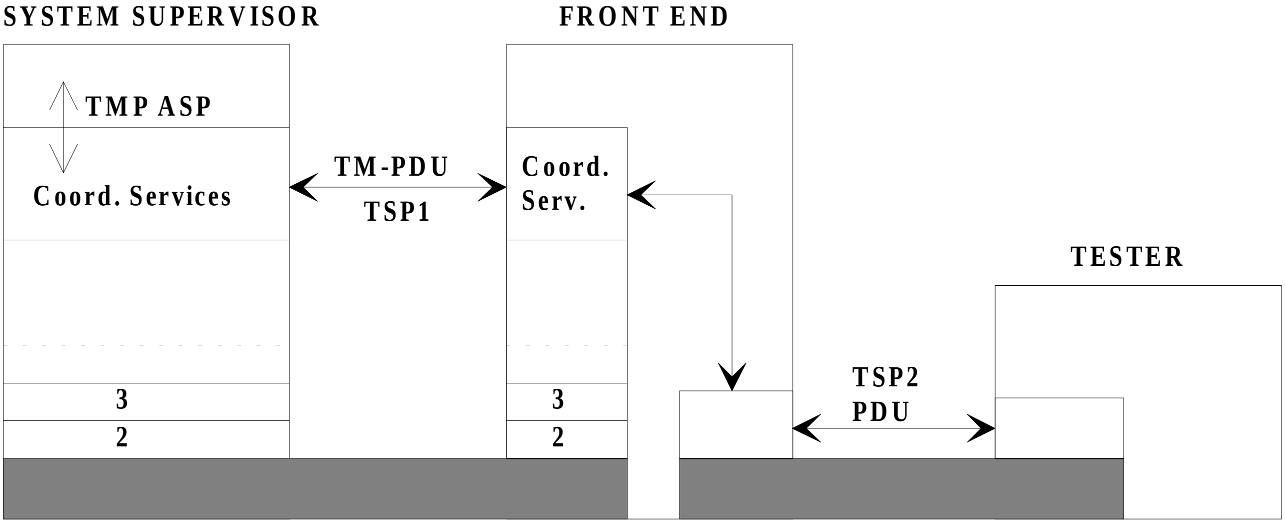

Figure A.3: Protocols of NIT Test Co-ordination Procedure

TSP1 messages decoded by Front End are relayed to/from a PT using a protocol (named TSP2 in the figure), whose implementation is local to each Front End and its PTs. Another Front End can use another TSP2 protocol to drive its PTs.

TSP1 is an application protocol defined in order to provide the user with the service of execution of a NIT test session in all its logical phases, typically: opening, execution and collection of results. The TSP1 is defined in terms of service primitives and messages. This allows to define a common way of access to the services and a common (standard) communication interface that allows to drive different testers. A TTCN ATS can rely on the synchronization services supported by TSP1.

All the concepts outlined above are dealt with greater detail in some ETSI [18] and EURESCOM [22] publications.

A.1.4 The actual Test Co-ordination Procedures

Each party involved in the test campaign must have an agreement on how the test synchronization and co-ordination will be actually handled. This refers to the method that has been implemented in the ETSs. The synchronization can be performed using different approaches:

a) Automatic synchronization: testers are managed and test procedures and messages are processed with an automatic and fully synchronized and integrated method. This method assumes that all the testing tools involved in the test are required to handle TSP1 messages.

b) Semi-automatic method: management of testers (configuration, transfer of trace files) is performed manually and test execution is performed automatically. This method assumes that only a part of the TSP1 messages has been implemented. The philosophy is that setting up the configuration of testers and getting back the trace files are operations that are performed manually. The ETS can anyway trigger such manual actions by prompting opportune messages and warnings on a man-machine I/O device.

c) Manual synchronization: the test procedures are not automated. A phone dialog between human operators will be needed to convey the messages and actions that must be manually performed on the testers on each test side.

A.1.5 Guidelines for NIT session management

Protocol specifications normally include an Implementation Conformance Statement (ICS) proforma, a set of entries presented in a tabular format, used to identify implementation options (IXIT proformas are also usually available).

In a general context, traditional ICS and IXIT proformas are not sufficient for the test execution since a NIT session may involve more than one Network Operator and test laboratory. As a first step in the test campaign, the organizations involved should agree on:

a) period of time in which the test campaign will be carried out, including an estimation of the time required to complete the test campaign;

b) people involved in the test campaign in each of the organizations performing the tests;

c) information on whom to contact to exchange all the necessary information, when and how;

d) requirements on any of the organizations participating in the test concerning the co-ordination procedures (for example what possible mechanism has been implemented in each side);

e) documentation to be used;

f) test cases to be executed (selected Test Case List) based on the information included in PICS and PIXIT documents.

For this purpose, the NIT methodology implies that along with the ATS also a set of ICS and IXIT -like proformas are developed, which must be filled in and exchanged among the involved organizations ahead of execution time.

A.1.6 Relevance of ISO/IEC 9646 to the NIT methodology

As regards the relationship between the NIT methodology and the main concepts and information contained in the relevant Parts of the ISO/IEC 9646 framework, the following points, among others, may serve as a raw "road map" for a NIT specifier:

- Part 1: relevant - NIT uses similar concepts and terminology.
- Part 2: partially relevant - most ISO/IEC 9646 Test Methods are not applicable to NIT (NIT uses only MPTM).
- Part 3: relevant - the concurrent TTCN is an important component of the NIT methodology.
- Part 4: partially relevant.
- Part 5: not relevant in the NIT context.
- Part 6: partially relevant in the NIT context.
- Part 7: relevant - ICS are important components of the NIT methodology.

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The following material, though not specifically referenced in the body of the present document (or not publicly available), gives supporting information.

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