The VITAL Network Resource Architecture

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Abstract

TINA aims to provide an architecture based on distributed computing technologies that will enable telecommunications networks to support flexible introduction and control of new advanced services. The provided services and the supporting network and computing infrastructure will be managed in an integrated fashion. Network management aspects in TINA are addressed by its Network Resource Architecture (NRA), which has so far concentrated on Connection and Configuration management, with Accounting, Fault and Performance management aspects to follow.

VITAL is a European collaborative research project that aims to validate a long-term telecommunication architecture, based on TINA, through the design, realisation and trials of a large scale system. This paper presents the VITAL work related to the realisation of the network resource architecture in the areas of resource configuration, connection and accounting management. The problems encountered are highlighted and the architectural solutions adopted are presented, together with examples of operation that illustrate better the design of the VITAL NRA system.

1. Introduction

TINA has defined a Network Resource Architecture (NRA) [1] that covers management areas of Connection, Configuration, Fault, and Accounting Management. Some of these areas have been defined in a great level of detail (e.g. Connection Management) while some others have only started being designed (e.g. Accounting Management) and even some are not yet defined at all (e.g. Performance Management).

VITAL (Validation of Integrated Telecommunication Architecture for the Long-term) is a European collaborative research project of the ACTS (Advanced Communication Technologies and Services) programme that aims essentially to validate a long term Open Distributed Telecommunication Architecture (ODTA) based on TINA. The concepts and specifications developed by TINA have been followed in areas where a good definition of the relevant models and objects existed. In other areas, VITAL followed its own approach.

This paper intends to present a summary of the work related to VITAL Network Resource Architecture [7]. The problems encountered and the solutions adopted by VITAL are presented. In addition, an example is given in order to illustrate the design of the VITAL telecommunication software system. Some TINA concepts are introduced in the paper but the reader should be familiar with the basic aspects of TINA Network Resource Architecture and its relevant terminology.

In summary, this paper has the following structure. Section 2 discusses the status of TINA network resource architecture. Section 3 presents the design and realisation of VITAL network resource architecture. In both sections exist separate subsections for resource configuration, connection and accounting management. Section 4 presents scenarios concerning the use of VITAL NRA for ATM technology networks. Finally, the paper closes with a summary and conclusions regarding the validation of TINA NRA in VITAL.

2. Current Status in TINA

2.1 Resource Configuration Management

While the functionality of Resource Configuration Management in TINA has been identified for quite some time, the current state of the relevant specifications and the overall architecture are pretty immature. The latest specification [1] represents a complete change compared to the previous one [10]. VITAL specification has taken into account input from all TINA specifications prior to [1] and has introduced additional concepts and models. VITAL approach is documented in [11] and will be fed back to TINA-C for the next version of the Network Resource Architecture [1].

The main requirements of RCM for managing network, service and computing resources are the following. RCM should maintain an inventory of resources under its influence and manage their relationships in the form of a *resource map*; it should ensure the map is updated with newly installed or deleted resources; it should allow the activation, deactivation, reservation and release of resources; and it should support automatic resource installation through the DPE wherever possible.

A key aspect of RCM is the maintenance of resource related information. Since the resource information is object-oriented, a major requirement is a computational construct offering a database-like access mechanism. This should provide access to objects representing the resources and should allow to navigate their relationships in a flexible fashion. Such a generic access interface is provided by OSI System Management (OSI-SM) and we have mirrored its capabilities in a generic computational interface for the resource map. The adoption of this approach means we can exploit TINA Network Resource Information Model (NRIM) specifications by mapping them directly to information objects handled by the resource map. In addition, the use of a OSI-SM-like computational interface implies that resource maps can be easily federated due to the hierarchical nature of the relevant information model. While this type of interface is powerful and *generic*, clients of the resource map may provide simpler, task-oriented interfaces, targeted to particular activities.

A key architectural addition to TINA RCM is the consideration of the management resources themselves, i.e. the computational objects offering TINA management services, in addition to the network, service and computing resources. For example, the Connection Management Configurator (CMC) is a computational entity that sets up and *manages* the Connection Management computational objects, based on topological information. Such an object is a manager for management resources and should belong to a new domain defined in VITAL, the Management Configuration Management (MCM). Subsequently, the other RCM domain considered in VITAL is the Network Topology Configuration Management (NTCM) domain which deals with the management of static network resources. In summary, the VITAL RCM modelling has started from existing concepts in TINA but modified and extended them to create a design suitable for a real prototype. VITAL RCM system is described in section 3.1.

2.2 Connection Management

Since the early times of TINA-C activities, Connection Management has deserved particular attention. Considered the core of TINA Network Resource Architecture, it was intentionally decoupled from the resource configuration management area. While this area deals with management of static resources, Connection Management addresses the management of dynamically allocated connectivity resources. It has been defined and specified in a level of detail in [3,4]. The *graph* information model was first proposed to represent connectivity but latter on it has proven to be too 'heavyweight' and the terminology not always adequate. Therefore, TINA has proposed another information model, based on the first one but simpler and more appropriate from the terminology point of view. However, some important mechanisms have not yet been included in the new Network Resource Architecture [1].

Currently, Connection Management in TINA is satisfactorily defined regarding the general mechanisms required for setting up and releasing connections, though unfortunately, it still contains a number of deficiencies. Some of them have already been resolved, for example the large amount of operations required to provide simple functionality, but some others still remain open. An overall definition on how to handle Quality of Service (QoS) in a technology independent manner, is an example of the still incompleteness of TINA. QoS generic negotiation mechanisms need to be introduced at different levels of the CMA, as well as at the service management level [13]. Another open issue, is the mapping between stream flows, which are by nature unidirectional, and network flows that might be bi-directional. The model proposed by TINA does not explicitly preclude this mapping but does not explain either what is the most suitable approach regarding this issue. The mapping has to be flexible enough to allow different possibilities of supporting one or more stream flow connections over a single network flow connection (e.g. ATM VP). As an alternative, it maybe useful to send a stream flow over two different network flow connections, for security reasons for example. In addition, the structure of the Endpoints (Stream Flow End Points, Network Flow End Points and Reference End Points) has not yet been clearly defined. The use of Reference End Points (RFEPs and ANFEPs) is ambiguous as is the whole procedure of resolving the Stream Flow End Points by associating Network Flow End Points belonging to different layer networks. Furthermore, scheduling, routing and performance are still some of the open aspects which make federation not very well defined. There is very little on accounting for connectivity resources and finally, the most important limitation in current TINA specifications, which is pertinent not only to the Network Resource Architecture, is the lack of a consistent way of defining object behaviour.

For an implementation and validation project like VITAL it is very important to find a common understanding of the behaviour of TINA computational objects. A compromise between a very generic but complex approach and a more specific, simple but comprehensive solution has been followed. In summary, VITAL did not intend to solve all the open issues but it has identified some important inconsistencies and unspecified areas, proposed some solutions and provided valuable input to TINA Network Component Specification.

2.3 Accounting Management

Accounting Management in TINA is not yet considered stable enough and complete. The dynamic, flexible and distributed nature of TINA presents a challenge regarding accounting functionality and features. The current work undertaken in TINA, presented mainly in [1][8], presents the requirements and principles for a flexible, distributed, reliable, multi-domain accounting management architecture. The work is mainly focused on resource level accounting from an information viewpoint.

TINA specifies the decomposition of the accounting management activities in four cycles, namely Usage Metering, Classification, Tariffing and Billing. The usage metering cycle is the first step and the basis for all the other cycles. Its purpose is the generation, collection and logging of resource usage information. In the classification cycle collected information is classified and categorised. In the tariffing cycle the charges are calculated taking input from the classification cycle and the tariff structure. Finally, in the billing cycle the bills are produced, stored and forwarded to customers according to the billing schedule.

TINA accounting management architecture defines an accounting management context as the object that specifies the details of accounting management to be performed in each stage of the accounting cycle. The introduction of the accounting management context concept facilitates the dynamic, flexible, distributed and reliable aspects of the architecture.

Unfortunately, despite the fact that TINA accounting management principles and architecture are attractive, they are not yet directly implementable. In addition, the current specifications are mainly focused at the information viewpoint while there is a lack of computational specifications. VITAL considered the principles and architecture presented in [1][8] but extended and refined them, defining a generic but implementable accounting management model, specifying the accountable resources and defining the metrics applied to them.

3. VITAL Network Resource Architecture

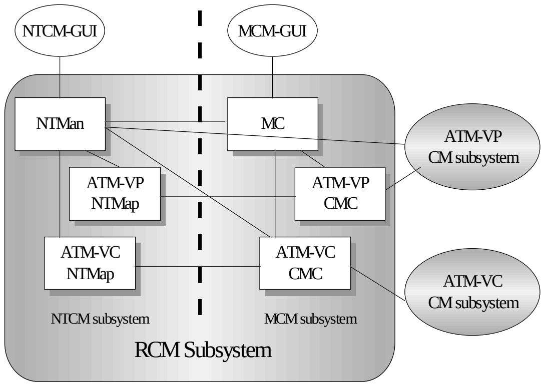
VITAL Network Resource Architecture has been applied to the management of ATM-VC and ATM-VP layer networks. The basic components of this architecture are depicted in Figure 1, and described in the following sections.

3.1 Resource Configuration Management

The computational design of VITAL RCM follows TINA documents prior to NRA 3.0 [1] with some deviations and novel aspects documented in [11]. A key deviation with respect to TINA is the division of VITAL RCM system into two subsystems, Management Configuration management (MCM), managing management resources, and Network Topology Configuration Management (NTCM), managing network topology resources.

Both subsystems have a subsystem manager computational object; MC in the case of MCM and NTMan in the case of NTCM (Figure 1), responsible for the integrity of the respective subsystem. The MCM comprises the Connection Management Configurator (CMC) computational objects within one Connectivity Provider domain. There exists one CMC instance for every layer network within that domain, responsible for the configuration of the computational objects in the

Connection Management system. This configuration is tightly coupled to the topology of the layer network, provided by the NTCM subsystem, but distinct in the sense that the CMC manages Management Resources (the CM Computational Objects), whereas the NTCM subsystem manages Network Topology Resources.



Legend:

CM	Connection Management	MCM	Management Configuration Management
CMC	Connection Management Configurator	NTCM	Network Topology Configuration Management
GUI	Graphical User Interface		
MC	Management Configurator	NTMan	Network Topology Manager

Figure 1: VITAL Network Resource Architecture

The NTCM comprises instances of the Network Topology Map (NTMap), one per layer network, within each Connectivity Provider Domain, in the same way to the CMCs in the MCM subsystem. The NTMap manages the topology map of one layer network. There exist two layer networks in VITAL, ATM Virtual Path and ATM Virtual Channel, in a server-client relationship. The NTMap is influenced by TMN methodologies and specifications and provides a generic, CMIS-like interface that allows to navigate the information objects that constitute the map in a very flexible fashion. The NTMan provides task-oriented, higher abstraction interface, with operations tailored to the needs of its client objects. The NTMan checks also the validity of clients' requests and thus maintains the integrity of the maps. This is particularly useful in the case of server-client networks, where a change in one layer / map potentially means changes to another layer and map, respectively.

VITAL RCM considers two cases of configuration: initial and dynamic reconfiguration. The initial configuration is a total configuration of the Connection Management system, carried out immediately after the bootstrapping of the system and reflecting the initial state of the network. The dynamic reconfiguration reflects any subsequent changes made to the map, with the consequence of reconfiguring partly the Connection Management system. A scenario for dynamically adding or removing a ATM VPC and the necessary reconfiguration are presented in section 4.1.

3.2 Connection Management

The set-up of a connection and negotiation process in VITAL

The computational model implemented in VITAL follows the one proposed by TINA. TINA Business Model and Reference Points defined in [5] were also taken into account. The proper behaviour has been added and a minimal set of operations and parameters have been implemented in order to coherently set-up and release connections.

Whenever a connectivity session is required, the Communication Session Manager (CSM) is contacted in the retailer domain. As a result of the stream binding realised at the service level, a set of connections is required in order to accomplish the service session demands. These connections are explicitly requested to the CSM. This computational object is responsible for negotiating with the terminals involved, the common information needed to run a session. Both, the type of codification of the stream flows (e.g. a_law for audio, MPEG for video) and the transport protocol are negotiated between the CSM and the Terminal CSM (TCSM) objects. At the consumer domain, the TCSM object manages the mapping between the codec information and the transport protocols. In VITAL second prototype, a simple mapping has been considered; this means that no multiple choices are offered to the CSM for it to decide which should be taken depending on the terminal capabilities. Basically, it has been assumed that all users will have the protocol determined by the source Stream Flow End Point (SFEP) and the connectivity providers will always have the needed technology (in case of VITAL, ATM). Therefore, the mapping is being done in the terminal in a very simple but efficient manner (this is foreseen to be enhanced for the next prototype). As a consequence of this approach, the CSM does not have to take care of specific technology parameters. The QoS information is decided at the service level, the codec's are negotiated at the CSM level and once agreed, the terminals will do the mapping between the service level QoS and ATM specific parameters. This information is then directly passed to the Layer Network Coordinator (LNC), a computational object which is by nature technology dependent.

The package composed by the LNC and subordinate objects (i.e. the CPs) is always technology specific; at least one instance of each of these objects must exist for each technology domain. The object that takes care of the specific information in the consumer domain is the TLA (Terminal Layer Adapter). There is one TLA per layer network. The Connection Co-ordinator (CC) computational object is the contact point at the connectivity provider domain. The current CC version in VITAL has been kept simple since only one technology is involved (i.e. ATM) but the need of having the CC controlling the adapters (peer-to-peer and client-server) and the definition of some kind of federation at the CC level have been identified. A CC is meant to be instantiated at each connectivity provider domain. When more than one connectivity provider is involved in providing a connection and each of them owns a different technology, the existent federation mechanisms defined at the level of the LNC do not apply any more. Since LNCs are technology specific they are supposed to federate only within the same technology domain.

The Federation Mechanism in VITAL

The VITAL demonstrator will be deployed over an ATM network by four network operators (Belgacom, CSELT, Telefónica, and Portugal Telecom). In order to make services available and interoperable across all domains, there is a need to support the establishment of connections through different network domains.

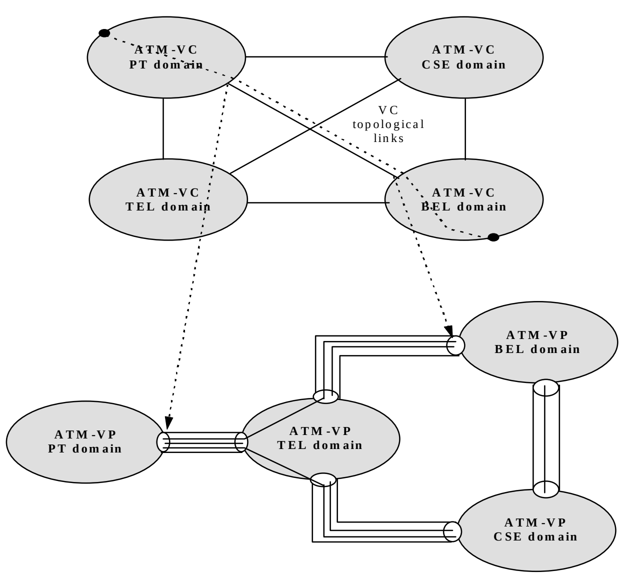


Figure 2: Federation at VP layer network supports federation at VC layer network

In spite of federation relationships can be defined at any layer network, there may be implications upon the choice. For instance, considering the configuration of ATM VC layer network shown in Figure 2, ATM VC topological links are established using trails in the ATM-VP layer network across all domains. If it is possible to set up a VP trail from Portugal Telecom (PT) to Belgacom (BEL) domain, it would be possible to define a topological link in the VC layer network between the corresponding domains of these operators. This situation implies that a request for a VC trail from a point in PT domain to a point in BEL domain goes transparently to Telefonica (TEL) domain, as shown in the figure. However, if there is not such VP trail, then the VC trail is established involving also TEL domain in the VC layer network. These considerations are useful when defining federation relationships between network operators, and are tightly coupled to the implications from the enterprise viewpoint.

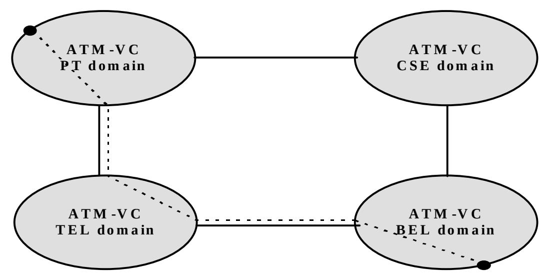


Figure 3: Different federation relationships

Federation relationships are supported by the LNC computational object. Each LNC offers the interfaces to create, control and destroy tandem connections through the corresponding domain. In principle, a LNC can be requested to establish a trail which starts or finishes in other domains. The LNC analyses which part corresponds to its own domain, and requests its corresponding NML-CP to establish and set-up that part, and to neighbour LNCs (those which are reachable through a topological link) for the remaining parts if any. Routing is made, using the network address of the end points, normally depending on the prefix of the given addresses.

Current specifications in VITAL consider that federation relationships may change, so LNC routing tables can be modified through the configuration interface, by specifying the name of the neighbour domain (this is used to get the reference of the neighbour LNC federation interface), the topological links between domains, and the list of network addresses which are reachable through the neighbour domain (this can be specified as a group by defining their prefixes).

Operations and parameters defined at the interface offered to the CC are also considered in the federation interface, with the addition of parameters which define a negotiation policy between the domains. These parameters determine, for instance, how accounting is to be performed, or whether monitoring information on the tandem connection is needed.

Federation interfaces can be applied also to avoid a deep hierarchy of CP computational objects, as it provides a mechanism for horizontal decomposition of the control of the network (see Figure 4).

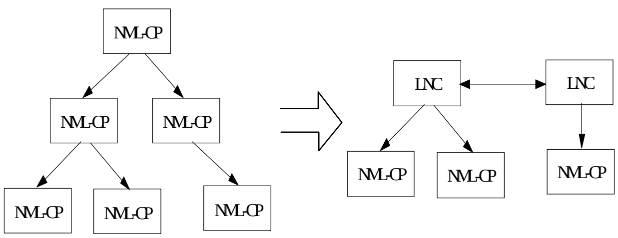


Figure 4: Decentralisation of connection management component hierarchy using LNC federation

3.3 Accounting Management

The accounting management model specified in VITAL follows as closely as possible the principles set in TINA accounting management architecture. For the second trial of VITAL the main focus was on the specification and implementation of the resource level metering cycle. This task is concerned with the definition of the accountable objects and the metrics applied to them, as well as with the definition of an implementable information and computational model applicable to both Retailer and Connectivity Provider domains for usage metering.

An accountable object is the modelling concept that represents a real resource which is subject of accounting management. The mapping between a real resource and an accountable object is not necessarily one to one. A real resource can be represented by more that one accountable object, and an accountable object may represent more than one real resource. The accountable objects can represent resources that belong to several TINA layers and to several aspects of TINA architecture. These resources can be service level, resource level, network, management and computing resources.

The possible network resources that are subject of accounting management can be the resources defined in TINA NRIM [9]. Such resources are, Subnetwork, LayerNetwork, Topological Link, Link Termination Point, NWTTP, NWCTP, NWTPPool, Connection, Subnetwork Connection, Tandem Connection, Edge and Trail. In addition to the above resources which are technology independent, it is possible to define a series of technology dependent accountable resources that correspond to the specific technology of the layer network.

Since the Connectivity Provider offers connectivity services to its clients, the network resources that constitute the connectivity fragment of TINA NRIM (Connection, Subnetwork Connection, Tandem Connection, Edge and Trail) appear to be the most suitable ones to be subject to accounting management. In VITAL, the Trail has been selected to be the accountable resource and the Trail Manager (TM) to be the accountable object that represents this resource.

The information and computational models for accounting management in VITAL are defined in a generic manner, so that it can be performed on both service and network resources. In principle, accounting management in VITAL is event driven. The accountable objects generate accountable events, each time the state of the accountable resource changes. In VITAL the following Accountable Events have been defined: registration, request, accept and complete. The Registration, Accept and Complete events model changes in the state of the service accountable resources. The Request event happens each time a change occurs in the state of the Trail that effects the usage of the service. Such a change can be noticed when one or more branches are added to or deleted from a Trail, or when one or more branches of the Trail became active or inactive.

The accounting events contain also usage metering information. This information is forwarded from the accountable object (TM in case of VITAL) to the Usage Metering Data object (UMData). The UMData object is responsible for metering the usage of the accountable objects (TM). It is also in charge of controlling the temporary logging of the accounting events and management of the logging records. In VITAL there is an instance of the UMData computational object per active Trail. Accounting events modelling was influenced from X.742 *Usage Metering Package*. Accounting event blocks contain information about the type of the event, the party that is related to the event, additional unit information and a time-stamp.

Upon the termination of the life-cycle of an accountable object, its corresponding UMData computational object reports the usage data to the Usage Metering Log (UMLog) computational object which stores the usage information in order to keep it persistent at the Connectivity Provider domain.

The metering and storage of accounting information in the connectivity provider domain is depicted in Figure 5.

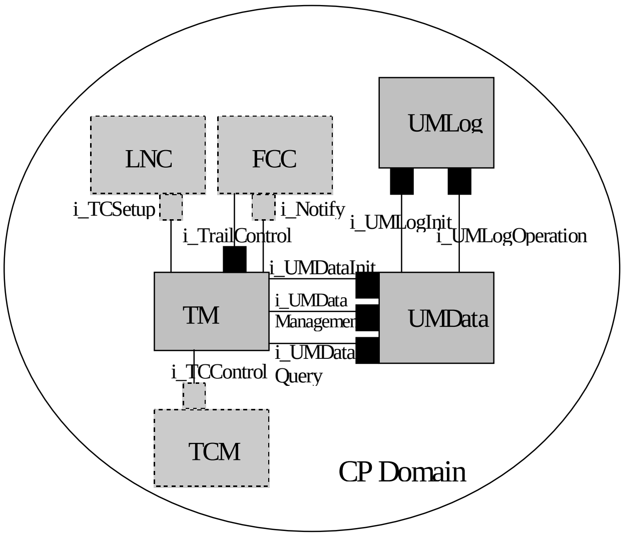


Figure 5 Connectivity Provider Usage Metering and Storage

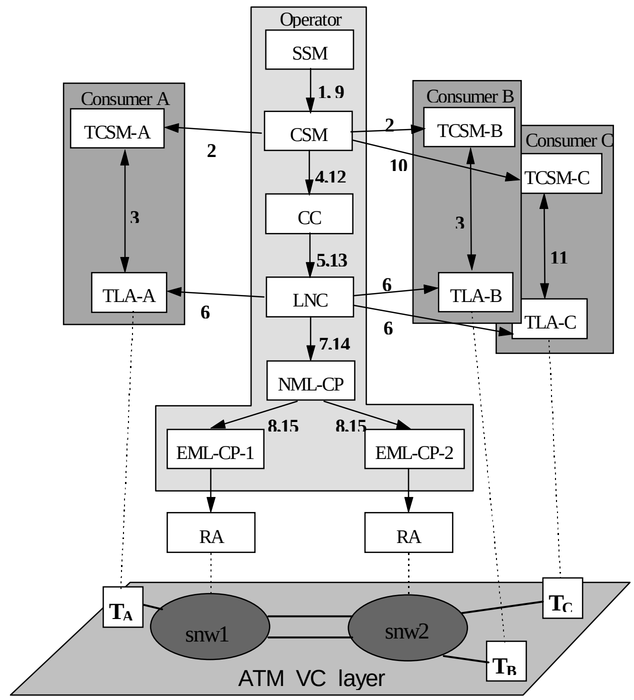
4. Scenarios applied to ATM Networks

The following scenarios illustrate the interactions among the computational objects described above. Two steps are considered. First, the configuration of the resources needed to set-up and release connections. Secondly, the procedures for providing the connectivity required by session level objects. In order to make clear the control of connections a simple network configuration will be considered where only one connectivity provider domain is involved (see Figure 6).

Note that in VITAL second trial the four operators act as both retailers and connectivity providers. Therefore the access part of ConS Reference Point (CSM-CC) [2] has not been considered.

4.1 Configuration scenario

In this scenario we consider the dynamic reconfiguration of connection management subsystems when adding or removing a new ATM Virtual Path Connection (VPC). As explained in section 3.1, the system is initially configured to reflect the initial topology of the network, both at the Virtual Channel (VC) and Virtual Path (VP) layers, which have a client-server relationship. The initial VPCs have been configured according to network planning activities. From then on, new VPCs may be added or existing ones may be removed by the network operator according to changing requirements. The steps involved in this process are the following, referring to the computational components of Figure 1.



Legend:

CSM - Terminal Communication Session
CC - Connection Co-ordinator
LNC - Layer Network Co-ordinator
CP -Connection Performer
NML - Network Management Layer
EML - Element Management Layer

TCSM - Terminal CSM
TLA - Terminal Layer Adapter
snw - Subnetwork
T - Terminal
RA - Resource Adapter

Figure 6: Configuration for scenario

- The NTCM-GUI retrieves and displays the current network topology from the VP and VC NTMap objects through the NTMan. The network operator may then request the addition / removal of a new VC topological link or VP trail through the graphical interface.
- The NTCM-GUI passes the request to the NTMan which checks its validity by accessing information in the VP and VC NTMap.
- In the case of a valid request, the NTMan asks the actual request implementation to the LNC of the VP Connection Management system. The latter implements it by passing it through the CPs and RAs to the actual ATM cross-connects.

- Upon successful completion, NTMan updates the VC NTMap with the topological link change (a VPC manifests itself as a topological link in the VC layer). The NTMan subsequently notifies the VC CMC about changes on the VC layer network topology.
- The VC CMC reconfigures the VC CM subsystem to take into account the topological change. From then on, VCC requests to it will be served according to the new topology of the VC layer network.

4.2 Set-up connection scenario

The aim of this scenario compared to Connection Management in TINA is to show how computational objects in the Consumer Domain (TCSM and TLA) negotiate connection related parameters (e.g. QoS, VCI) with those located in the Connectivity Provider Domain (CSM and LNC). It is also important to highlight that the higher level components (i.e. SSM, CSM and CC)) are not aware of technology specific information (e.g., VCI values); this is handled by the Consumer Domain computational objects and the low level components (i.e. LNC and CPs). The scenario presented in this section is more focused on high level mechanisms rather then on technology specific ones. In addition, federation is not further described here due to its complexity. Details concerning this issue can be found in [12].

1. The chosen scenario is initiated by SSM, which requests CSM the creation of a communication session. The stream flow end points to be interconnected are given to the CSM together with the TCSM references.
2. The CSM then contacts each TCSM object located in each terminal in order to know the characteristics of the correspondent network flow end points (e.g. network address, layer network, media flow codification and network related protocols). By knowing this information, CSM can then perform the negotiation between the different terminals. Currently, in VITAL a simple negotiation process has been implemented. CSM looks for commonalties among the parameters provided by the different terminals and in order to take the final decision gives high priority to the choice of the source. Similarly, only a simple mapping between stream flow end-points and network flow end-points has been defined. This mechanisms will be enhanced in the next trial.
3. While each TCSM is a repository of the existent stream flow end-points, a TLA keeps track on the technology dependent information, which in the case of VITAL is ATM specific. The layer network type, the network address and the transport protocols are then requested by TCSM to TLA. Latter, when the VCI is chosen by the LNC in co-operation with the CP objects, the TLA helps the TCSM to resolve the mapping between stream flow end points and network flow end points.
4. The CC is a less complex object since the access part has not been considered in the current VITAL trial and only the ATM VC layer is handled. In the future, CC will choose the connectivity provider and the layer network based on constraints or/and requirements arising from consumer domains.
5. The LNC receives a request from the CC for the provision of a trail. The CC sends the network addresses of the terminals, the references of the associated TLA objects, and the correlation identifier.
6. The parameters mentioned above allow the LNC to contact the TLA objects and negotiate the VPI/VCI values, together with the connection parameters (e.g., quality of service and bandwidth), which are supported by the terminal for that connection. If a terminal was attached to a network point in the scope of other connectivity provider domain, the LNC would delegate the negotiation with the corresponding TLA to a federated LNC. The LNC is prepared to suggest some values of VPI/VCI and quality of service to the correspondent TLA. Currently in VITAL, the TLA is suggesting such values to the LNC since the mapping of QoS is totally done in the terminal and no constraints from the consumers have been considered yet. Nevertheless, the negotiation mechanism already exists for future enhancements.
7. The LNC then requests to its top NML-CP object to create a subnetwork connection among the identified network termination points. Each NML-CP deals with routing functionality in its own domain.
8. Each NML-CP determines the lower CP objects (finally, at Element Management Level, EML-CP) to request the connectivity for the subnetworks in the domain. EML-CP objects keep control on the use and reservation of the resources associated to a certain subnetwork, e.g., termination points and bandwidth associated to the subnetwork.

Up to this moment, resources have been reserved but they have not effectively been allocated in the real switches. This happens when there is a request to CSM to activate the connection graph (or some specific part of it). This request goes from the CSM down through the CC, LNC, NML-CP, and, finally, EML-CP. A Resource Adapter (RA) class of objects is used for interacting with the real switches. RA objects provide to each EML-CP independence over vendor's specific interfaces supported by the switches. This allows the use of the same CP objects over different switches, as it is the case in VITAL, where each operator has its own.

Once the connections in the switches are established and set-up, multimedia flows can be transferred between the different terminals involved in the communication session.

Add a Branch

Operations 9 to 15 enable to add a new branch to a point-to-multipoint connection. The CSM must re-negotiate the terminal capabilities with the parties involved. Similarly to the other terminals, the technology dependent parameters (including QoS) are negotiated at the LNC-TLA level. The mapping between QoS parameters concerning services and those network related is done within the terminal.

5. Conclusions

The validation effort of the TINA architecture performed in the VITAL project has driven to the identification of under-specified components behaviour and interfaces. In order to develop working services on a real multi-operator ATM network, TINA specifications have been refined and extended when needed. This work is currently being considered by TINA-C core team and will be reflected in final TINA-C specifications, in concrete Network Resource Architecture [1], Connection Management Specifications [4], Accounting Management [8], and Network Resource Configuration [10].

The experience achieved by mid-97 has been centred around Resource Configuration Management, Connection Management and Accounting Management. It is interesting to note that specifications developed in VITAL for Resource Configuration Management and Accounting Management are not only applicable to Network Resources, but also to the Service components of the TINA architecture, because of the generality of the initial information and computational models. These have been specialised for the network part, and next year will be applied for the service part. Another important aspect developed in VITAL is the way application stream flows and QoS requirements are mapped to network connections, and the implications of the architecture in the terminal side.

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6. References

[1] *TINA Network Resource Architecture*, version 3.0, TINA document no. TB_v3.0_97_02_10, TINA-C, Feb. 1997.

[2] *The ConS Reference Point*, version 1.0, February 97

[3] *Connection Management Architecture*, document no. TB_JJB.005_1.5.94, March 95

[4] *Connection Management Specifications*, document no. TP_NAD.001_1.2_95, March 95

[5] *TINA Business Model and Reference Points*, version 4.0, Approved Public Version, May 97

[6] *Network Resource Information Model Specification*, TINA Baseline Draft, May 96

[7] *Connection Management Specifications for VITAL 2nd phase*, VITAL internal draft document, May 97

[8] *Accounting Management Architecture*, version 1.3 (Draft), Engineering Note, February 1996.

[9] *Network Resource Information Model*, Document No. TB_LRS.011_2.0_94 TINA-C, December 1994.

[10] *Network Resource Configuration Management*, version 2.0, October 1996.

[11] G.Pavlou, D.Griffin, "*Realising TMN-like Management Services in TINA*", to appear in the Journal of Network and Systems Management Special Issue on TINA, 4th quarter 1997.

[12] J. Pavón, E. Montes, "*Network Provider Domain Federation*", TINA 97.

[13] J.Rajahalme, T.Mota, F.Steegmans, P.F.Hansen, F.Fonseca, "*Quality of Service Negotiation in TINA*", TINA 97.