Telecommunication Services Engineering : Definitions, Architectures and Tools

Jean-Pierre Hubaux [1], Simon Znaty [1,2]
[1]EPFL, ICA, Switzerland, jean-pierre.hubaux@epfl.ch
[2]ENST-Bretagne, RSM Department, France, Simon.Znaty@enst-bretagne.fr

Abstract
This paper introduces *telecommunication services engineering* through a definition of services, of network architectures that run services, and of methods, techniques and tools used to develop services. We emphasize the Intelligent Network (IN), the Telecommunication Management Network (TMN) and TINA architectures; we also discuss the impact of the Internet on these architectures.

Key words : telecommunication services engineering, network architectures, methods, techniques

1. INTRODUCTION TO TELECOMMUNICATION SERVICES ENGINEERING

The demand for advanced telecommunication services has increased enormously over the last few years. This has led to situations where network operators must deploy new services at a rapid pace when satisfying customer needs. The telecommunication monopolies have disappeared, and the fight for market shares has become fiercer than ever before. Furthermore, the demand for ever more specialized end-user services keeps growing, along with the demand for having the new services deployed within shorter and shorter time frames. The structure and function of networks must change, in order to cope with these new challenges. The telecommunications industry is witnessing a changeover from being interconnection driven to being service driven!
A new discipline called “telecommunication services engineering” is emerging. It encompasses the set of principles, architectures and tools required to tackle activities ranging from service specification to service implementation, service deployment and exploitation.

In this paper, we survey the different facets of this new area. In the second section, we define the term *service*. The third section introduces *service engineering*. In the fourth section, we emphasize the network architectures used to ease the introduction of telecommunication and management services. We particularly focus on the IN, TMN and TINA architectures and compare their features. The fifth section positions IN and TINA with regard to the Internet. The sixth section deals with the methods, techniques and tools used to build telecommunication services such as the object oriented approach, open distributed processing and the agent technology.

2. SERVICE DEFINITION

The word ‘service’ has become a magic word in the telecommunication world these last years. This word is somewhat fuzzy and ambiguous since there are so many aspects of services, and therefore, there is a need for explanation of some of the terms most often used.
Telecommunication services is a common name for all services offered by, or over, a telecommunication network.

The word service is used in several different contexts with somewhat different meanings. In the ISDN (Integrated Services Digital Network) world, three types of network services can be distinguished [1] :

Support services define the transmission capabilities between two access points, including routing and switching across the network. They correspond to « bearer services ».

Teleservices include capabilities for communication between applications. Teleservices are supplied by communication software in the terminals. Telephony, audio, fax, videotex, video telephony are examples of teleservices.

Supplementary services, also called features, complement support services or teleservices. Most well known supplementary services are related to the telephony teleservice (Call forwarding, three party conference, etc.), but they could of course be generalized to other teleservices.

Value added services are services that require storage/transformation of data in the network and are often marketed as stand-alone products. Examples of such services are freephone, premium rate, virtual private network and telebanking. Many value added services can be offered by special service providers connected to the network.

3. SERVICE ENGINEERING DEFINITION

Since the early 80's, the major trend in the area of service provision has been towards dissociating service control from the underlying network equipment. As a result, services have been seen as sets of interactions among software pieces running on top of the network infrastructure. Consequently, the concepts, principles and rules of service engineering were borrowed at a large extent from the software engineering area.

The telecommunications community was faced with a new challenge, which was to bring the telecommunication specific requirements together with software engineering. Interests grew up to integrate results from other disciplines such as security, verification and validation, database management systems, communication management, etc.

Service engineering can be defined as the set of methods, techniques and tools to specify, design, implement, verify and validate services that meet user needs and deploy and exploit these services over the current or future networks. Service engineering is a young discipline, but is a discipline in itself, as is protocol engineering.

Three important components are considered within the framework of service engineering (Figure 1):

• The *service creation environment* is a software engineering platform specialized for the development of telecommunication services.

• The *telecommunication network* contains the transmission and switching equipment. Each of these equipment may be seen as one black box that offers an application programming interface (API); this may be a signaling or management interface.

• The *network architecture* is responsible for controlling the network in such a way that a service's specific requirements get satisfied.

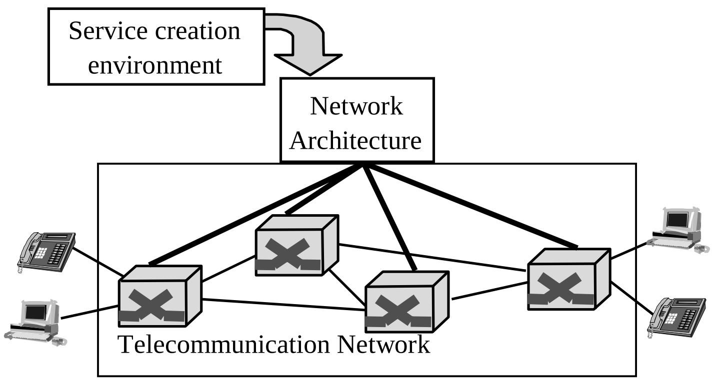


Figure 1: Components of Telecommunication Services Engineering

Service engineering covers three important domains :

• *Service creation*, where the service is considered as a distributed application running on the multiple nodes of a telecommunication network.

• *Service management* refers to the way a service is operated throughout its lifecycle.

• *Network management* refers to the management of network resources used to provide telecommunication services.

Therefore two kinds of services are involved, telecommunication services and management services.

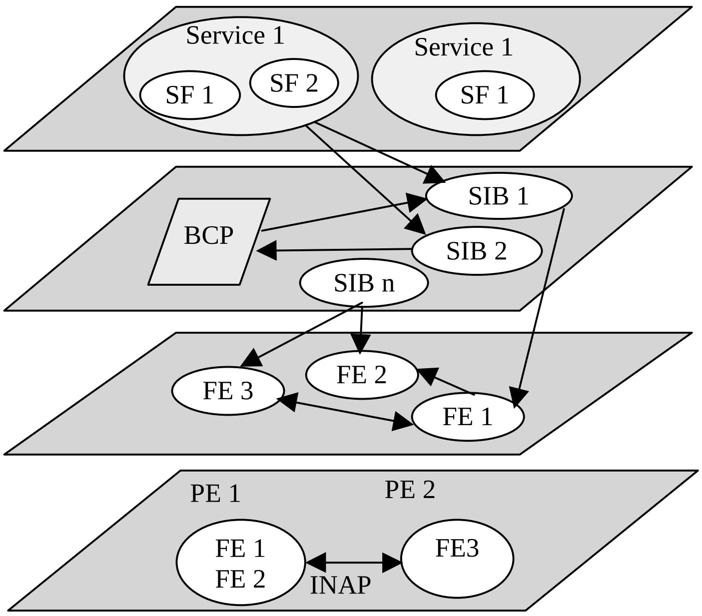
4. NETWORK ARCHITECTURES

4.1. THE INTELLIGENT NETWORK (IN)

The term *Intelligent Network* (IN) was first introduced by Bellcore in the 80's following the deployment of the green number service in the US. The IN is an architectural concept allowing a rapid, smooth and easy introduction of new telecommunication services in the network [2]. These services may be customized.

The architecture chosen is based on a centralized control. Service control is completely separated from call control. It is based on the existence of a signaling network linking all the switches. In the modern digital telephone network this signaling network does exist : it is called Common Channel Signaling n°7 (CCS7) network.

The ITU-T has defined the *IN conceptual model* (INCM) [3] which is not exactly an architecture but rather a methodology to describe and design an IN architecture. The INCM consists in four planes (Figure 2):



SF: Service Feature
SIB: Service-Independent Building block
BCP: Basic Call Process
FE: Functional Entity
PE: Physical Entity
INAP: Intelligent Network Application Protocol

Figure 2: IN Conceptual Model

The Service Plane (SP) describes services from a user's perspective, and therefore is of primary interest to service users and providers. It consists of one or more service features. A service feature is a service component; it may correspond to a complete service or part of a service. This composition principle enables the customization of services, i.e., the creation of services by the subscriber and not necessarily by the telecom operator.

The Global Functional Plane (GFP), deals with service creation and models the network as a unique and global virtual machine. This plane is of primary interest to service designers. It contains the Service Independent Building Blocks (SIBs) that are used as standard reusable capabilities to build features and services. There exists a particular SIB called Basic Call Process (BCP) from which a service is launched. In this plane, a service consists in a chain of SIBs which can be viewed as a script.

The Distributed Functional Plane (DFP) models a distributed view of an IN and is of interest mainly to network designers and providers. It describes the functional architecture of the Intelligent Network which is composed of a set of Functional Entities (FEs) executing actions. A functional entity is a network functionality. The two main functions are the Service Control Function (SCF) which contains the IN service logic and controls the overall execution of the service and the Service Switching Function (SSF) which provides a standardized interface between the SCF and the switch for the control of this switch. The other functional entities are the Specialized Resource Function (SRF) which performs user interaction functions (e.g., playing announcements or prompting and collecting user information) via established connections, the Service Data Function (SDF) which performs related data processing functions such as retrieving or updating user information, the Service Management Function (SMF) which handles the activities of service deployment, service provisioning, service control, service billing and service monitoring, and finally, the Service Creation Environment Function (SCEF) which allows a service to be defined, developed and tested on an IN structured network. Each SIB of the GFP is decomposed in the DFP into a set of client server relationships between one or more functional entity.

The Physical Plane (PP) corresponds to the physical architecture of the IN which consists in a set of physical entities and interfaces among them. This plane is of primary interest to network operators and equipment providers. The functional entities in the DFP are implemented into the physical entities. For example, the SCF becomes the SCP (Service Control Point) and the SSF is translated into an SSP (Service Switching Point). The interface between SSP and SCP for IN service execution is called INAP (Intelligent Network Application Protocol). INAP messages are encapsulated into SS7 messages that are exchanged between SS7 signaling points over 56 or 64 kbit/s bidirectional channels called signaling links. Signaling takes place out-of-band on dedicated channels rather than in-band on voice channels.

Figure 3 shows a simplified IN architecture. Such an architecture is well adapted to services needing a centralized database like the green number (sometimes called Freephone) service.

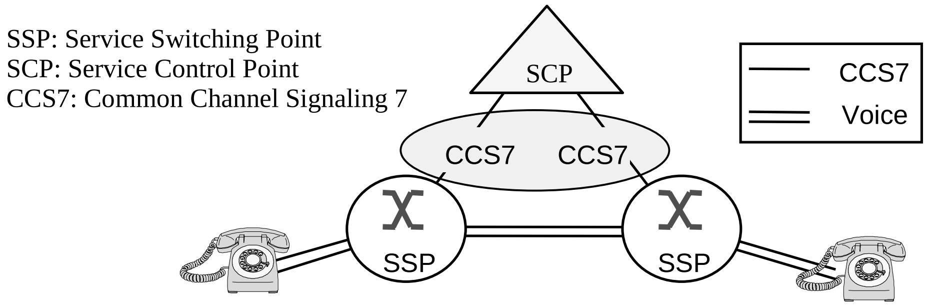


Figure 3 : Simplified IN Architecture

The IN will play a major role in the provision of mobile telecommunications services. Indeed they raise some specific problems to the tracking of mobile users and terminals. A key enabler for providing these kind of services is the IN capability. Mobile services need IN capabilities for mobility management and service control and as these services expand, they will put new demands on IN.

Each phase of development in the definition of the IN architecture is intended to produce a particular set of IN capabilities, known as a Capability Set (CS). Each CS is compatible with the previous CS and is enhanced to ensure that it is one stage closer to the final IN target. CS-1 was the first development phase.

CS-2, which was completed at the end of the first quarter of 1997, is the second standardized stage of the intelligent network evolution; it addresses the limitations of CS-1. CS-2 enables interworking between IN architectures to provide international services, allows the management of both IN services and IN equipment through the TMN, and supports enhanced IN services such as mobility services.

CS-3 addresses issues such as full IN/TMN integration, full IN/B-ISDN integration and full support for mobile/personal communications systems.

4.2. THE TELECOMMUNICATION MANAGEMENT NETWORK (TMN)

Parallel to the IN standardization, the ITU-T has defined the *Telecommunication Management Network* (TMN). TMN enables the federation of the equipment that constitute the telecommunication network, produced generally by different telecommunication vendors, to enable their control in a uniform, global and efficient way [4].
Management of telecommunication networks may be defined as the set of activities of monitoring, analysis, control and planning of the operation of telecommunication network resources to provide services to customers with a certain level of quality and cost.

• **Monitoring** is defined as the process of dynamic collection, interpretation and presentation of information concerning objects under scrutiny [5]. It is used for general management activities which have a permanent continuous nature such as the systems management functional areas (i.e., performance, configuration, fault, accounting, security).

• **Analysis** is applied to monitoring information to determine average or mean variance values of particular status variables. Analysis is application specific. It can range from very simple gathering of statistics to very sophisticated model based analysis [6].

• **Control** is the process by which changes in the managed network are affected.

• **Planning** is defining the network topology and sizing every network element in order for the user to obtain any given service in optimal conditions with regard to quality and price.

The set of capabilities necessary for network management relies on a reference structure which identifies the main TMN components and interfaces. The TMN can be considered according to three views: information architecture, functional architecture and physical architecture.

The **TMN Information Architecture** provides a data representation of the network resources for the purpose of monitoring, control and management. The approach adopted for the specification of the information model is object oriented. The TMN information architecture also defines management layers which correspond to levels where decisions are made and management information resides (business management layer, service management layer, network management layer, element management layer). The ITU-T proposed a generic network information model [7]. Genericity enables the model to be applicable to different network technologies (e.g., ATM[1], SDH[2], PDH[3]). The model is currently applicable to both network element and network management layers.

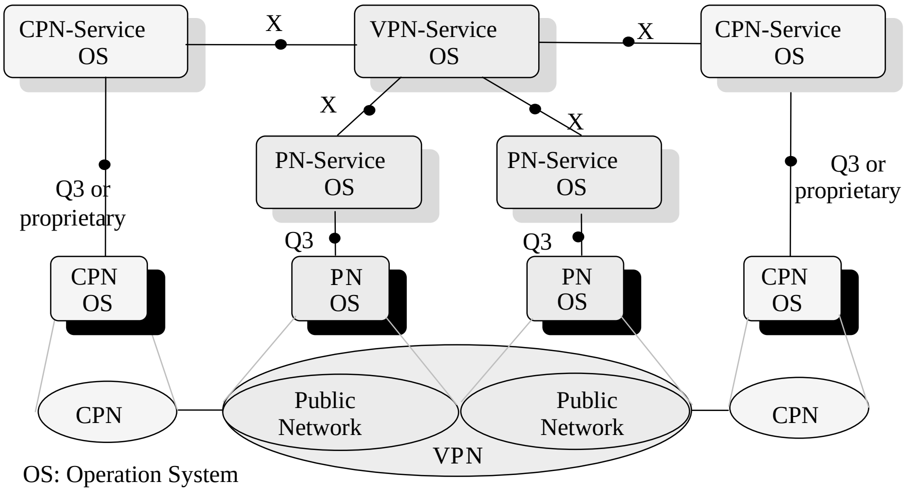
The **TMN Functional Architecture** describes the realization of a TMN in terms of different categories of function blocks and different classes of interconnection among these function blocks, called reference points.

The **TMN Physical Architecture** corresponds to the physical realization of the functional architecture. Each function block becomes a physical block or a set of physical blocks (OS, Operation System) and reference points are transformed into interfaces. Among these interfaces, we can find the Q3 interface between an OS and the managed resource or between two OSs of a given management domain and the X interface between two OSs belonging to different TMN domains. The TMN is seen as a set of connected physical blocks, each of them executing a set of TMN functions. To ensure interoperability, the specification of an interface requires the use of compatible communication protocols and compatible data representation. The exchanges of information between two management systems are performed by means of management operations and notifications through the CMIS[4] service and CMIP[5] protocol.

Although the TMN was defined with network management in mind, it can be used to provide a multitude of services. One of the most sophisticated of these services is the Virtual Private Network (VPN). VPN is a telecommunication service that provides corporate networking among geographically dispersed customer premises, based on a shared public switched network infrastructure.
Figure 4 shows the physical architecture of a VPN (Virtual Private Network) configuration management system [8]. The configuration management architecture consists of a set of OSs, the CPN OS that manages the CPN resources, the PN OS that manages the public network resources, the PN-service OS which is responsible for the management of the services offered over the public network (e.g., a virtual path service in an ATM network), the CPN-service OS whose role is to administer the services provided over the CPN, and finally the VPN-service OS for the management of the VPN service. The X interface enables interactions among the VPN service actors, i.e., the customer, the service provider and the network provider. The Q3 interface takes place between OSs of a given management domain.

---

[1] ATM : Asynchronous transfer Mode
[2] SDH : Synchronous Digital Hierarchy
[3] PDH : Plesiochronous Digital Hierarchy
[4] CMIS : Common Management Information Service
[5] CMIP : Common Management Information Protocol



OS: Operation System
PN: Public Network
CPN: Customer Premises Network
VPN: Virtual Private Network

Figure 4: VPN Physical management architecture

Obviously, the IN and TMN architectures overlap [9]. For instance, one TMN application such as billing and one IN application such as Freephone must be tightly related because VPN billing should be handled in a consistent way with TMN billing. This shows that unless both IN and TMN architectures are made more consistent, the interworking of IN and TMN applications would be very difficult. Moreover, it will be difficult to support two independent architectures while applications of both architectures must interoperate. The TINA architecture encompasses an integrated IN/TMN architecture.

4.3. TELECOMMUNICATIONS INFORMATION NETWORKING ARCHITECTURE (TINA)

The evolution of the IN calls for new facilities such as flexible control of emerging multimedia, multisession, multipoint, broadband network resources, and services interoperability across diverse network domains. To meet these requirements, the TINA consortium defined a global architecture that enables the creation, deployment, exploitation and management of services worldwide [10].

The goal is to build a reference model for open telecommunication architectures that incorporate telecommunication services and management services, and integrate the IN and TMN domains. TINA makes use of the latest advances in distributed computing (Open Distributed Processing, ODP [11] and Object Management Group, OMG [12]), and in object orientation to ensure interoperability, software reuse, flexible distribution of software and homogeneity in the design of services and their management.

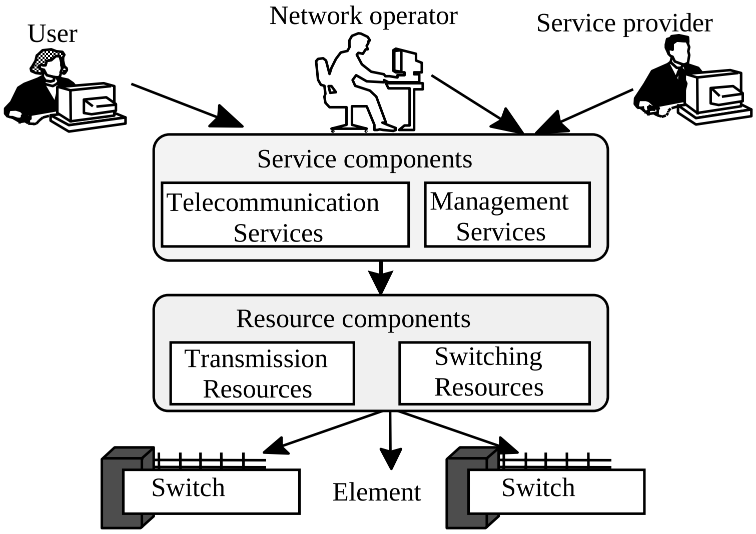


Figure 5: The TINA architecture

The layers of the TINA architecture divide application objects into different domains (figure 5) : The service layer where service components provide value added services with their management integrated, and the resource layer where resource management components provide an abstraction of the network resources used to supply the service (e.g., components that enable services to establish, maintain and release connections). Service and resource management components run over a distributed processing environment (DPE) [13]. At the lowest layer of the architecture, we can find the physical resources such as transmission links, switches and terminals.

TINA is composed of three architectures:

• The **Computing Architecture** defines the concepts, principles and rules for telecommunication software reusability and interoperability by relying on ODP. These concepts are applied for the design of both telecommunication and management services. The computing architecture also provides a prototype of a distributed processing environment (DPE) for TINA services. It describes the function of this DPE, its main components and its programming interface. The TINA DPE may be regarded as an abstraction of distributed systems such as CORBA.

• The **Service Architecture** provides a set of concepts to build and deploy telecommunication services. In a TINA system, a service consists of a set of components that interact with each others and are deployed over a DPE. The service architecture defines the required objects for the realization of a service, their composition and interactions. Moreover, a universal service component model (USCM) has been proposed to promote reusability during service development. The three important concepts in this architecture are :

  • The concept of session which refers to service activity [14].
  • The concept of access which relates to the associations between the user and the service.
  • The concept of management for service management.

• The **Network Resource Architecture** defines a set of generic concepts for the realization of network resource management applications. Among these generic concepts, we can find a new area added to the TMN management functional areas, namely, connection management. Another important concept is the "computational object" to model both managers and agents. Finally, the network resource architecture proposes a generic network resource information model (NRIM) based on [7].

4.4. NETWORK ARCHITECTURES COMPARISON

The following table summarizes the different characteristics of the three network architectures presented above.

Criteria	IN	TMN	TINA
Types of services	telephony-based services (UPT, Freephone service)	Management services (VPN configuration management service)	Multimedia services, Management services
Support networks	All types	All types	Broadband networks
Method for Service creation	Functional approach	Object oriented Approach	Distributed object Oriented approach
Components for Service creation	SIBs	SMFs	USCM
Main elements of the Architecture	SCP, SSP	OS, NE	SSM, CSM
Communication	SS7 (INAP)	X, Q3 (CMIS/CMIP)	CORBA (IDL)
Standardisation body	ITU-T	ITU-T	TINA-C

Table 1: Comparison of the three telecommunication architectures

Acronyms

UPT: Universal Personal Telecommunications
SIB: Service Independent building Block
SMF: Systems Management Function
USCM: Universal Service Component Model
SCP: Service Control Point
SSP: Service Switching Point
OS: Operation System
NE: Network Element
SSM: Service Session Manager
CSM: Communication Session Manager
SS7: Signaling System 7
INAP: Intelligent Network Application Protocol
CMIS/CMIP: Common Management Information Service/ Common Management Information Protocol
CORBA: Common Object Request Broker Architecture
IDL: Interface Definition Language
ITU-T: International Telecommunication Union – Telecommunication sector
TINA-C: TINA Consortium

The IN architecture, in its present state of development, is confined to basic-telephony call-control capabilities. This architecture is mostly deployed over the public switched telephone network, ISDN and mobile networks. TMN provides management services for the management of telecommunication networks and services. It could be deployed over any network. TINA is an architecture that embraces IN and TMN within a framework based on ODP. This architecture enables the deployment of complex services along with their management (e.g., multimedia services).

The way services are built with the IN is functional. A service is seen as a chain of elementary instructions called SIBs (e.g., translate, algorithm and compare). The TMN applies the object oriented approach since resources that are managed are represented as objects. To build a management application, the designer may make use of basic software units called Systems

Management Functions which provide some capabilities (e.g., state management, log control, and alarm reporting). Within TINA, a service consists of a set of service components that will run over CORBA. Every service component specification derives from a universal service component model (USCM) which may be seen as a skeleton that every service component should conform to.

The IN architecture consists mainly of SCPs that control the execution of a service and SSPs that correspond to switches with a standardized interface for the dialogue with SCPs. The TMN architecture is composed of OSs that contain the management applications and NEs that are the resources to be managed. The TINA architecture makes use of two important objects, the service session manager (SSM), which is responsible for the control of the execution of a service of a given type, and the communication session manager (CSM), which supplies an end-to-end connectivity to the SSM.

The control network in the case of IN, TMN, and TINA is different for each architecture. Signaling System 7 is considered in the case of IN for exchanges of INAP messages between SCPs and SSPs; a Data Communication Network may be used for CMIS/CMIP interactions between the OSs and NEs. In the case of TINA, CORBA messages are exchanged between the SSMs and CSM.

5. IN, TMN, TINA AND THE INTERNET

The architectures described so far have been defined with telecommunication services in mind, without really taking into account the development of the Internet. However, it is now clear that the growing popularity of the Internet is dramatically changing the landscape of the communications marketplace. The two separate worlds of the Internet and telecommunications need to converge and should be integrated to fulfill the promise of the information superhighways. This section evaluates the current status of this convergence.

5.1. IN AND THE INTERNET

Today, several architectures have already been proposed, promoting the integration of the IN and the Internet and in particular the World Wide Web. Among them, we can find the reference model proposed by the IETF PINT group [15] and the WebIN architecture designed by HP [16].

In [15], Internet-based devices such as WEB servers and SNMP-based management systems are connected to IN devices. Four services are considered as case studies. These are Click-to-Dial, Click-to-Fax, Click-to-Fax-Back and Voice-Access-to-Content. The Click-to-Dial service enables a user to initiate a PSTN outgoing as well as incoming call by hitting a button during a WEB session. The Click-to-Fax service enables the user to click on a button to send a fax, the click-to-Fax-Back allows the user to receive a fax by clicking on a button, and finally the Voice-Access-to-Content service enables the user to access content-based services such as WEB pages.

In [16], the proposed WebIN architecture resembles in different aspects to the classical IN architecture. The major differences are: (1) the service data point (SDP) and the service management point (SMP) are connected to the Internet, (2) SCPs are connected to SDPs through a distributed processing environment (DPE) that might be the Web (HTTP/CGI) or CORBA, and (3) the role of the SCP is confined to finding out the correct reference of the SDF that corresponds to the service actually invoked.

In addition, the SCE relies on the WEB service creation environment (HTML, Java). After writing the service logic using these technologies, the service creator simply uploads her service logic into the WEB service dedicated to her.
The goal of the WebIN architecture is to show how WWW technology and IN technology complement each other. It proposes a hybrid architecture where service logic and subscriber information (SDF) are implemented on an Internet-based signaling and distribution network and interfaced to the SCF for bearer channel and resource control.

5.2. TMN AND THE INTERNET

The complexity of telecommunication networks, i.e., enterprise and carrier networks, has grown over the last two decades. The management of these networks has followed different approaches because carrier networks apply TMN, while enterprise networks consider an SNMP[6]-based management approach.

The borders between public (carrier) and private (enterprise) networks are becoming increasingly transparent, the distinction between both types of networks may soon be irrelevant from a network management point of view [17]. The challenge that the progressing convergence of networks presents is to manage the concerned network management worlds in a consistent way, while still preserving the vast investments in existing networks and network management solutions.

The new management framework should consider:
• The use of WWW technology for representing management tasks. This requirement addresses the fact that the user interfaces provided by WWW browsers have received wide acceptance and are the common interface to server-based information services.
• The introduction of cooperative sessions for network management. This requirement acknowledges the fact that management in modern networks is shared among many parties.
• The interworking with SNMP-based, CMIP-based and proprietary management systems. This requirement is a consequence of the need to interoperate with existing management systems, especially at the element management layer.

5.3. TINA AND THE INTERNET

From its very beginning, TINA has been a project funded and carried out by the traditional telecommunication companies, network operators and telecommunication vendors. The main assumptions on which TINA were based are:
• The services will continue to be primarily provided by the network or by network-based servers rather than by the terminals.
• The B-ISDN will rely on end-to-end-ATM.
• The pace of the telecommunication evolution will remain under the control of the main telecommunication stakeholders.

The first assumption is inherited from the IN. For TINA, it led to a high level of complexity in the Service Architecture. Meanwhile, Internet services became extremely popular; the generalization of browsers, the deployment of Internet telephony and the multiparty session over the MBone showed that it was possible to implement a high number of services over a network of limited capabilities. Indeed, the role of the terminal became completely different with its increasing processing power which enables the implementation of sophisticated functions in software such as audio and video decoders, and with the advent of new software

[6] SNMP: Simple Network Management Protocol

paradigms thanks to JAVA (e.g., applets) which permits downloading executable code during a given service session.
This shows that network operators should concentrate on the provision of services that cannot be supported by the terminals such as UPT and routing-based services, in order to not confine themselves to being mere connectivity providers.

The second assumption explains why so much effort has been put on the specification of the connection management architecture. However, it becomes obvious that the B-ISDN will in fact be based on the Internet/Intranet technologies, provided that the appropriate resource reservation, billing and security mechanisms are implemented. Therefore the TINA architecture should also encompass connectionless networks such as Internet.

The third assumption is clearly based on the monopolistic tradition in this domain. However, in the meantime, the development of the Internet protocols has proved that it is possible to "do first and standardize later". Incremental development is now the usual practice.

This analysis shows that most of the assumptions that gave birth to TINA are no longer valid because of the complete change of landscape brought on by the Internet. However the Internet has not fully met the challenge of the provision of multiparty, multimedia services. In particular, the guarantee of a given quality of service is still a problem that needs to be solved. That means that although TINA will not be implemented as it was initially intended, some good concepts could be inherited from it. Recently, several TINA proponents have been studying the applicability of TINA to the Internet [18][19][20].

6. TECHNIQUES

The advanced information processing techniques are playing a major role in the realization of telecommunication services and the underlying network architectures. Among these techniques, we find object oriented methods, open distributed processing, and the agent technology.

6.1. OPEN DISTRIBUTED PROCESSING

A telecommunication service is a distributed application that runs over the multiple nodes of a telecommunication network
The ODP reference model jointly defined by ISO and ITU-T provides a framework for the design of distributed systems with the introduction of viewpoints. Each viewpoint represents a different abstraction of the original system. Informally, a viewpoint leads to a representation of the system with emphasis on a specific concern. Five viewpoints were identified: enterprise, information, computation, engineering and technology (figure 6).
The *enterprise* viewpoint is concerned with the overall environment within which an ODP system is to operate. The *information* viewpoint focuses on the information requirements of the system, and deals with information object types, together with their states and permitted state changes. The *computational* viewpoint shows processing functions and data types, abstracting away from the underlying hardware structures via transparency functions. The *engineering* viewpoint establishes transparency services utilizing concepts from operating systems and communications. The *technology* viewpoint is concerned with the realization of an ODP system in terms of specific hardware and software components. ODP has been extensively used for the definition of TINA [21].

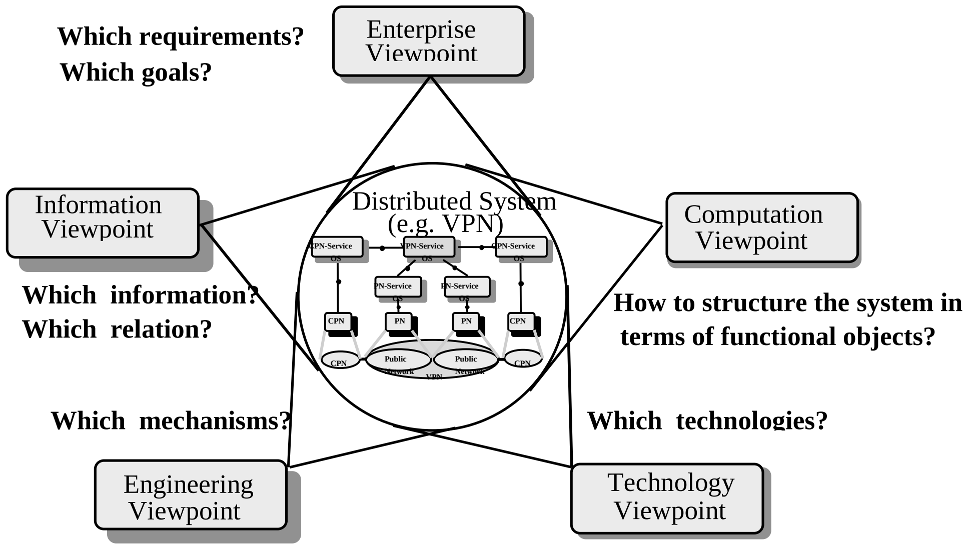


Figure 6: ODP viewpoints: different projections of a system

6.2. MOBILE AGENTS

An agent is a program, which, with a certain degree of autonomy, performs tasks on behalf of a user or an application. An agent may move between network sites and cooperate with other agents to achieve its goals [22].

Agent development finds its roots in two research domains : intelligent agents stemming from artificial intelligence, which studies the capabilities of learning and decision making of cooperative autonomous entities ; and mobile code technology that enables programs to migrate from a machine to another, while preserving their execution environment. This latter domain is evolving at a fast pace due to the emergence of languages such as Tcl [23] and Java [24], and of their portable execution environment.
The use of agent technology for telecommunication services engineering is a very hot topic in particular in the area of service and network management [25][26]. It lies within the boundaries of areas such as telecommunications, artificial intelligence and software engineering. This can be seen as an advantage because it promotes the convergence of research results from different communities.

6.3. OTHER TECHNIQUES

Among the other techniques not detailed in this survey, we mention formal methods for the verification, validation and testing of telecommunication services before deploying them ; the goal of formal methods is to improve the reliability of these services [27]. Indeed, the rapid growth of the number of services makes the problem of proving that the services conform to their specification more acute: in fact, reacting rapidly to customer or market needs requires introducing new services only a few months or even a few weeks after the first specification; such a short interval makes it quite impossible to go through the tedious and long (several months) tests usually performed for new services. This problem is getting worse since there are more services continually added to the networks, contributing to the overall complexity. Services must all work correctly without hindering the function of other services; this last problem is often referred to as the “feature interactions problem”. These obstacles, on the road to rapid service introduction, call for new approaches to increase confidence in the service.

Figure 7 summarizes the interrelations among the different network architectures of telecommunication services engineering and the impact of techniques on these architectures. TMN, TINA and ODP follow the object oriented approach. TINA applies the ODP concepts, principles and viewpoints and integrates the IN and TMN architectures. Finally, mobile or intelligent agents may be perceived as an emerging technology for the next generation of telecommunications [28].

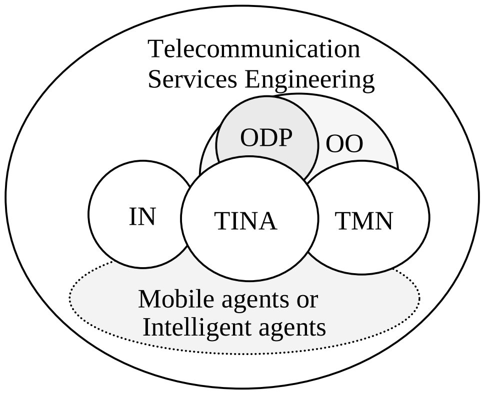


Figure 7: Interrelations between network architectures and impact of techniques

7. CONCLUSION

As we have seen, telecommunication services engineering is composed of two major parts:

• A part related to the network architecture which is in charge of executing the service in the network. The IN evolution will notably encompass its integration with the International Mobile Telecommunication 2000 architecture [29] for rapid introduction of services and efficient service control. In addition, there is an increasing interest in bringing telephone services provided by PSTNs to Internet users through the IN.
The TMN evolution is integrating CORBA-based management particularly for the new task of service management. Interoperability will play a very important role. Indeed, if a service extends over multiple networks, network operators of these networks should be able to negotiate service provision and contract establishment with each other. Although the effort spent towards the provision of an integrated IN/TMN architecture called TINA has been important, TINA in its current status is not deployed. Indeed, TINA is not evolutionary but rather revolutionary with regards to IN and TMN. This would lead a network operator to reconsider his investments in IN and TMN architectures, which is not acceptable. Moreover, CORBA is immature for the deployment and execution of telecommunications services which require real time constraints. CORBA is currently foreseen for management aspects only. Finally, TINA did not take seriously into consideration its possible deployment over the Internet. The IN CS-3, which is the IN long-term architecture, should reuse the TINA computing architecture and part of the TINA service architecture.

• A part related to methods, techniques and tools for the analysis, design, implementation, verification, and validation of telecommunication services. These methods, techniques and tools rely heavily on the object oriented approach and open distributed processing.
Unfortunately, there is little theoretical background behind the topics we have discussed; therefore, experimentation and prototyping are the only means available today to show the feasibility of the proposed concepts and scenarios. More research is needed to establish solid foundations.

Telecommunication services engineering is an important research domain at the boundaries of software engineering and telecommunication systems. It draws much attention from network operators, service providers and telecommunication vendors since it is an important source of income. Specifically, how the Internet will develop within or in parallel with these architectures is still an open question.

ACKNOWLEDGMENTS
The authors are indebted to Holly Cogliati and Constant Gbaguidi for their valuable comments on early drafts of this paper.

REFERENCES

[1] ITU-T Rec. I.210, Principles of Telecommunications Services supported by an ISDN and the means to describe them, 1988.
[2] ITU-T Recs. Q120x, Q121x, Q122x, The Intelligent Network, 1993.
[3] ITU-T Rec. Q1201, Principles of Intelligent Network Architecture, 1992.
[4] ITU-T Rec. M.3010, Principles for a Telecommunications Management Network, 93.
[5] Joyce, J., et al., *Monitoring Distributed Systems*, ACM Trans. on Comput. Syst., Vol 5, No. 2, May 87.
[6] Mansouri-Samani, M., Sloman, M., *Monitoring Distributed Systems (A Survey)*, Report, Imperial College, Dept of Computing, 1993.
[7] ITU-T Rec. M.3100, Generic Network Information Model, 1992.
[8] Gaspoz, J. P., Hubaux, J. P., Znaty, S., A Generic Architecture for VPN Configuration Management. Journal of Network and Systems Management, *Plenum Press*, Vol 4, N° 4, 375, Dec 96.
[9] Pavlou J., Griffin, D., An Evolutionary Approach towards the Future of IN and TMN, *Baltzer ICN*, Special issue on telecommunications services, Jan 98.
[10] Barr, W. J., Boyd, T., Inoue, Y., The TINA Initiative, *IEEE Communications Magazine*, 70, March 93.
[11] ITU-T Rec. X901, Basic Reference Model of Open Distributed Processing - Part1: Overview and Guide to Use, 1994.
[12] OMG, The Common Object Request Broker : Architecture and Specification. OMG Document N° 91.12.1, Rev. 1.1, Dec. 91.
[13] TINA-C, TINA Distributed Processing Environment (TINA-DPE), TINA-C Deliverable N° TB_PL001_1.0_95, July 95.
[14] Koerner, E., Danthine, A., Towards a TINA-based Framework for Collaborative Work. *Baltzer ICN*, Special issue on telecommunications services, Jan 98.
[15] Faynberg, I., Krishnaswamy, M., Lu., H., A Proposal for Internet and Public Switched Telephone Networks (PSTN) Internetworking, Internet Draft, 1997.
[16] Low, C., The Internet Telephony Red Herring, *in Proc. of Conf. IEEE GLOBECOM*, Eds., IEEE Press, 1996.
[17] Bogler, G., Internet Technology for Integration of Carrier Network Management (TMN) and Enterprise Network Management, Internet Draft, 1998
[18] Smith, C., Applying TINA-C Service Architecture to the Internet and Intranets, Proc. Conf. TINA’97, 1997.
[19] Zen, G., et al., Value Added Internet: a Pragmatic TINA-based Path to the internet and PSTN Integration, Proc. Conf. TINA’97, Santiago, 1997.
[20] Licciardi, C. A., Minerva, R., Moiso, C., Spinelli, G., Spinolo, M., TINA and Internet: An Evaluation of some Scenarios, Proc. Conf. TINA’97, Santiago, 1997.
[21] TINA-C, TINA Computational Modeling Concepts, TINA-C Deliverable N° TB_A2.HC.012_1.2_94, Feb 95.
[22] Wooldridge, M., Agent Based Computing, Baltzer ICN, Special issue on telecommunications services, Jan 98.
[23] Ousterhout, J. K., TCL: An Embeddable Command Language, Conf. Winter USENIX'90, pp 133-146.
[24] Sun Microsystems : « The Java Language Environment : A White Paper », 1995. http://javasoft.com/whitePaper/java-whitepaper_1.html.
[25] Goldszmidt, G., Yemini, Y., Meyer, K., Erlinger, M., Betser, J., Sunshine, C., Decentralizing Control and Intelligence in network Management , *in Proc. Int. Symp. Integrated Network Management*, Eds., Chapman Hall, 1995, .

[26] Mountzia, M. A., A Distributed Management Approach based on Flexible Agents". *Baltzer ICN*, Special issue on telecommunications services, Jan 98.

[27] Etique, P. A., Hubaux, J. P., Logean, X., Service Specification and Validation for the Intelligent network, *Baltzer ICN*, Special issue on telecommunications services, Oct 97.

[28] Magedanz, T., Rothermel, K., Krause, S., Intelligent Agents : an Emerging Technology for Next Generation Telecommunications ?, Proc. Conf. IEEE INFOCOM'96, San Francisco, 1996.

[29] Panda, R., Grillo, D., Lycksell, E., Mieybégué, P., Okinaka, H., Yabusaki, M., IMT-2000 Standards : Network Aspects, *IEEE Personal Comm. Mag*., August 97.