

The Evolution of the Telecommunication System from a Vertical to a Horizontal Architecture

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Today the telecommunication network and the computer network look quite similar to each other in terms of technologies and equipment and one may be tempted to believe that they have the same origin. However, they were originally built to serve different purposes and use different technologies. Their architectures were therefore completely different. The telecommunication network had a vertical architecture while the computer network was built according to a horizontal architecture. With time, both the needs and the means were changing and the architectures of the two networks are converging. This paper is aiming at shedding light on the architectural differences between the original telecommunication network and the computer network. The understanding of the differences is essential to understand the evolution of the telecommunication network. The paper starts with a study of the traditional telecommunication system. Next, the architecture of the computer network is studied. A transition journey of the telecommunication network is then presented. Finally, a promising future telecommunication architecture is presented.

The most important question when any new computer architecture is introduced is "So what?"

– Anonymous

1 Introduction

The evolution of an architecture results from the dynamics between the human needs such as shelter, security, worship, religion, etc. and the means such as available building materials and builder's skills. The telecommunication network architecture makes no exception. Originally, the telecommunication network and the computer networks were serving different needs and using different technologies. They had therefore different architectures. The telecommunication network had a vertical architecture while the computer network was built according to a horizontal architecture. With time, both the needs and the means were changing and the architectures of the two networks are converging. Today they are getting so close to each other that one can have the problems to remember and understand their different origins. This paper is aiming at shedding light on the architectural differences between the original telecommunication network and the computer network. The understanding of the differences is essential to understand the evolution of the telecommunication network.

This paper is not a historical recitation of the telecommunication networks story with all the events and changes. It is not a detailed description of the technologies that are employed in the telecommunication and computer networks. Nor does it provide scientific analyses and evaluation of the telecommunication and computer networks but rather personal reflections of the author based on observations that may not always be rigorously proven.

This paper is aiming at giving a concise but comprehensive explanation on the fundamental difference in the architecture of the telecommunication and computer networks in terms of concepts, principles and goals. This difference, although huge in the 1960s, is now vanishing! It is important, however, to understand and remember it in the development of future telecom and computing convergent network system. Attempts to clarify the motivations for promotion and introduction of the technologies are also carried out in the paper partly by the review of literature and partly by logical reasoning.

The paper is intended to be light, easy and pleasant to read. Therefore, technical details are intentionally omitted and simplifications are made wherever possible. The paper starts with a study of the traditional telecommunication system. Next, the architecture of computer network is studied. A transition journey of the telecommunication network is then presented. Finally, a promising future telecommunication architecture is presented.

2 The 'Vertical' Telecommunication System

Communication at Long Distance

As indicated by the prefix 'tele', telecommunications extends the geographical distance in interpersonal communication, ie. permitting two persons located far from each other to exchange information with each other.

Although the telegraph was the first electronic telecommunications system the telephone system is the most central one in modern telecommunication. The

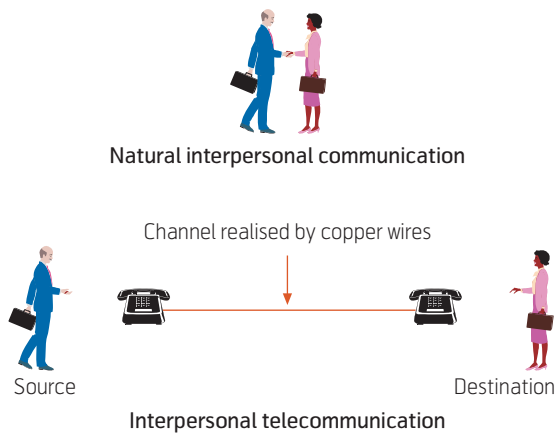


Figure 1 Telecommunication enables long distance communication



Figure 2 An early telephone

telephone system enables long distance two-way voice communication, ie. it allows two persons to have a conversation while being far away from each other. Alexander Graham Bell got granted the telephone patent, United States Patent No. 174,465 in 1876, which has proven to be one of the most valuable patents in history.

Designed for Optimal Use of Scarce Resources

In a simplified way, in order to permit two persons to communicate at long distance, one pair of telephones acting as both transmitter and receiver, and one pair of copper wires are used. When wishing to speak, the user had to whistle into the transmitter until the other party heard it. In early days, there was no network and telephones were wired 'privately' together in pairs. To be able to talk to a given number of persons the user must have as many telephones for the purpose. Figure 2 shows an early telephone apparatus.

One way to reduce the number of telephones is to connect the same telephone to all other phones. However, the number of copper wires is still rather high. To allow full connection in a set of n telephones the number of pairs of wires required is:

$$n!/2(n-2)! = n(n-1)/2$$

When n (the number of telephones) grows, the number of wires will grow faster. This is obviously not economical in large systems. Nor is it convenient when new telephones have to be installed since wiring with all existing telephones is necessary.

To reduce the number of wire pairs, telephone exchanges or switches are introduced. A switch is a device permitting to connect any line (copper pair) to any other line. From the early days, switching is done manually. It was then gradually done by electro-

mechanical, electronic and finally computerized switches. Figure 3 shows an operator room where the telephone calls are manually connected by human operators.

In a small network as shown in Figure 4a), a single switch is used to interconnect all the telephones. However, due to the number of telephones, the geographical distribution, and also in order to improve reliability, a multi-level switched network with alternative routes is used in the telephone network known as the Public Switched Telephone Network (PSTN). The telephone system was designed with resource optimisation as main principle.

Vertical Single-Service System

The telephone system is a network system consisting of numerous switches and cables which offers to the users the telephone service delivered on terminals attached to the Network Access Points (NAP). As shown in Figure 5 the network is quite often represented as a cloud whose internal structure is hidden.



Figure 3 Operator room – Frank Woods Telephone Museum Photos – Courtesy of Wally Tubbs

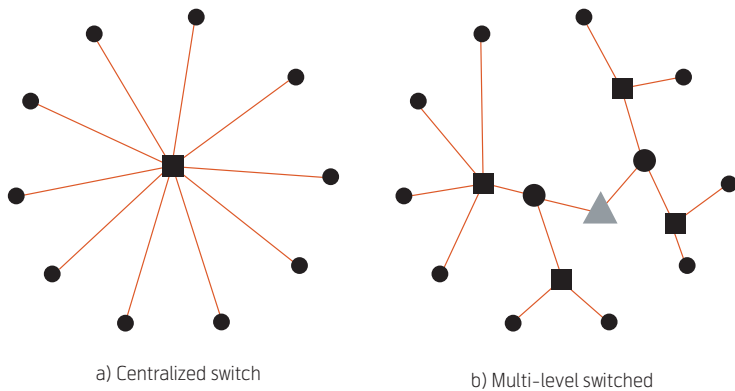


Figure 4 Switched networks

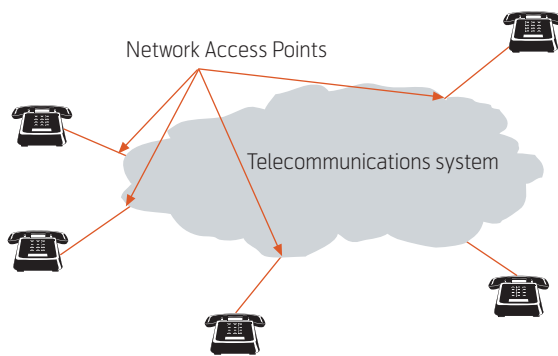


Figure 5 The telephone network as a cloud with numerous Network Access Points

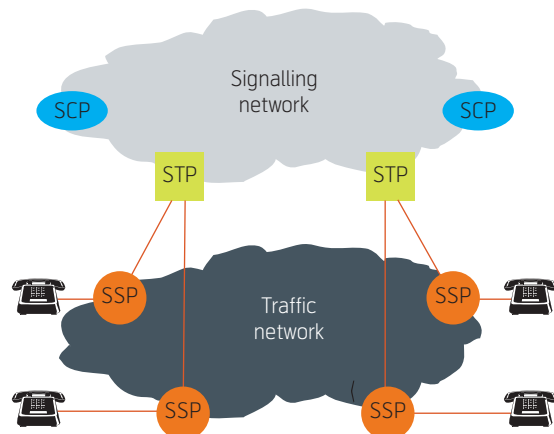


Figure 6 The telephone system consisting of two networks

Indeed, the ultimate goal of the telephone system is to provide a unique service, namely telephony to the users in the simplest way and to hide all the complexities of the network. The telephone system is hence built according to a *vertical architecture* with network system in the centre offering the voice service to the users at the boundaries of the system. The vertical architecture is characterized by the tight integration of the infrastructure in the bottom, i.e. cabling, switches, repeaters, etc. and the logical software com-

ponents on the top, responsible for the control and transportation of voice traffic.

More generally, every vertical system has its own protocols, nodes, end-user equipment or terminals and is built on principles and practices which aim at ensuring the availability, efficiency and reliability of the targeted service [1].

Dual Network System

The vertical architecture gives to the telecommunication operators the freedom to change and improve the network without affecting the users. In the 1970s, when it was time to migrate from the existing analogue telephone network to a digital network as shown in Figure 6 the telephone network got a new architecture actually consisting of two networks:

- A traffic network to carry the voice traffic;
- A signalling network to transport the signalling.

Signalling refers to the exchange of information necessary to notify the communicating party, to establish and to tear down conversations such as dialling digits, dial tone, accessing a voice mailbox, sending a call-waiting tone, etc. In the analogue telephone network, the signalling was transported in the same network as voice traffic and hence stole part of the network capacity. The two networks are also referred to as *signalling* and *data planes*.

In the 1980, the Signalling System No. 7 or simply SS7 was defined as an international standard by ITU-T, the standardization committee of the International Telecommunication Union, in its 1980 (Yellow Book) Q.7XX-series of recommendations [2].

As shown in Figure 6 the network SS7 is made up of three signalling nodes:

- Service Switching Point (SSPs)
- Signal Transfer Point (STPs)
- Service Control Point (SCPs).

The SS7 network has in fact a horizontal packet-oriented and layered architecture which is inspired by the OSI model. The OSI model will be explained in more detail later on. The introduction of SS7 shows that the telecom world started to recognize the flexibility of the horizontal architecture.

The 'Vertically' Integrated Services Digital Network

The vertical architecture, due to its efficiency and reliability gained a preponderant position in the telecom world. In the early 1970s when it was time for a digital network capable of accommodating both tele-

phony and also data services, the design of the new traffic network, called Integrated Service Digital Network (ISDN) was strongly influenced by this successful vertical architecture.

The Integrated Services Digital Network (ISDN) concept was formally defined by the CCITT in 1979. It has been created to be a single network to carry all communication services at the time, ie. telephony, data communication services, transfer of text and picture, etc., and in the foreseeable future. It is designed as a complete system offering services to user applications. It is worth remembering that the signalling network remains separate from ISDN.

ISDN is built according to the generic protocol reference model of ISDN depicted in Figure 7 [3]. The ISDN is a *Global Transport Network* using various transmission and switching techniques which is able to offer a *Global Transfer Service* to User Applications.

The Global Transfer Service is a service that offers a global connectivity with standardized classes of services, regardless of the addressing plans and the transport technologies used to transfer the information.

The User Applications pass user, control and management information via APIs to the respective user, control and management functional entities in the global transport network. All the user entities are collectively called the *user plane*, similarly all the control entities are called the *control plane*, and all the management entities are called the *management plane*. In principle, the three planes can be implemented as vertical separate networks.

The three 'vertical' planes constitute the main components of the ISDN Protocol Reference Model (ISDN PRM), whose objective it is to model the interconnection and exchange of information – including user information and control information – to, through, or inside an ISDN [4].

As shown in Figure 8 the user plane (U-plane) is composed of user protocol blocks and the control plane (C-plane) of control protocol blocks.

The *user plane* contains protocols that are responsible for the transparent transfer of information among user applications.

The *control plane* contains signalling protocols that are responsible for the transfer of information for the control of user plane connections, eg.

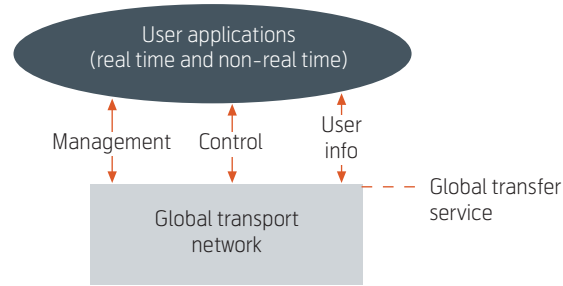


Figure 7 The Generic Protocol Reference Model for telecommunication networks

- Controlling a network connection (such as establishing and clearing down);
- Controlling multiple network connections for multimedia calls;
- Controlling the use of an already established network connection (eg. change in-service characteristics during a call such as alternate speech/unrestricted 64 kbit/s);
- Providing supplementary services.

The *management plane* contains management functions of resources and parameters residing in the protocols in both user plane and control plane.

The establishment of a communication is the result of cooperation of the control and management planes and the information transfer service provided may

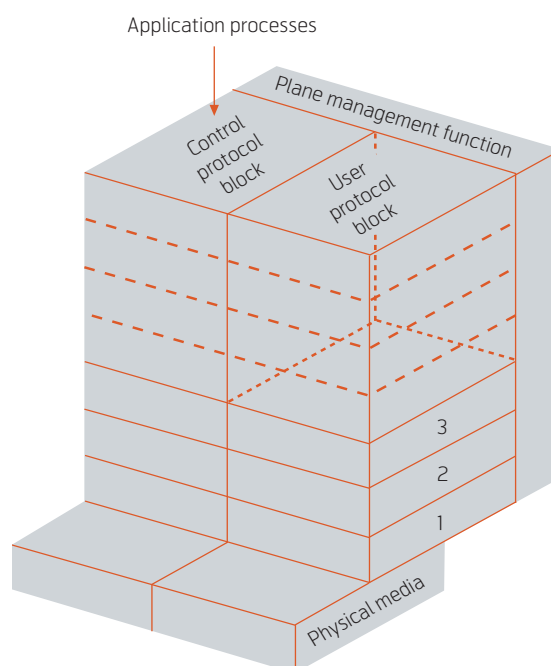


Figure 8 The ISDN protocol reference model (PRM)

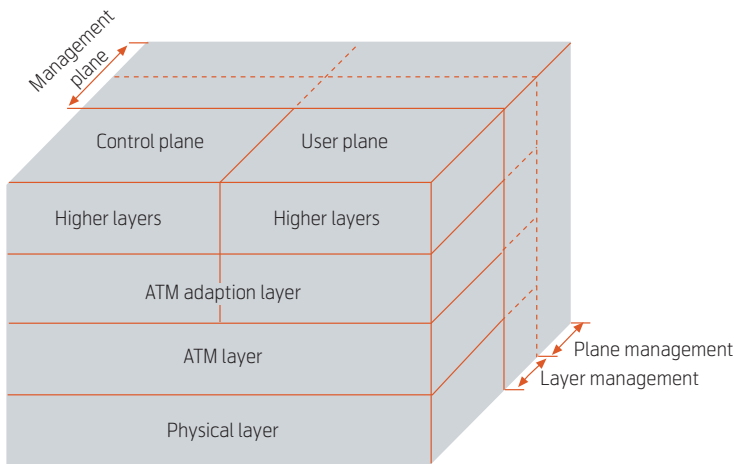


Figure 9 B-ISDN protocol reference model

have different characteristics; eg. connection-oriented, connectionless, on-demand, permanent, etc.

As shown in Figure 8, the ISDN protocol reference model includes the concept of layer which is introduced by the Open Systems Interconnection Reference Model (OSI Reference Model or OSI Model) which is an abstract description for computer network protocol design [5][6]. The OSI model will be described in more detail in later sections. However, not the whole OSI Reference Model but only the layer concept is applied for the U- and C-planes. The development of services is hence more complicated since mappings between the vertical planes and the

horizontal layers have to be done and this is not always a trivial task.

ISDN was deployed in the 1990s in Europe but was really not a widespread success.

More Verticality in Broadband-ISDN

The vertical philosophy continued to dominate the telecom world and in the 1980s, to cope with the demand of higher bit rates, a new vertical system called Broadband Integrated Service Digital Network was designed. Again, B-ISDN is a complete system with its own protocols, nodes, end-user equipment or terminals. The main technology adopted by B-ISDN is the Asynchronous Transfer Mode (ATM) which is capable of supporting both synchronous communication services and asynchronous data services. The vertical architecture of B-ISDN is reflected in the B-ISDN protocol reference model shown in Figure 9 where the vertical planes, ie. user, control and management planes, constitute the main components [7]. Superseded by the Internet and its protocol, B-ISDN was never deployed.

Telecommunication, a World of Silos

In the 1980s, to meet the demand for mobility in telecommunication, new complete mobile systems were again constructed and introduced. NMT (Nordisk mobiltelefonsystem), AMPS (Advanced Mobile Phone System), GPRS (General packet radio service), GSM (Global System for Mobile communications), UMTS (Universal Mobile Telecommunications Sys-

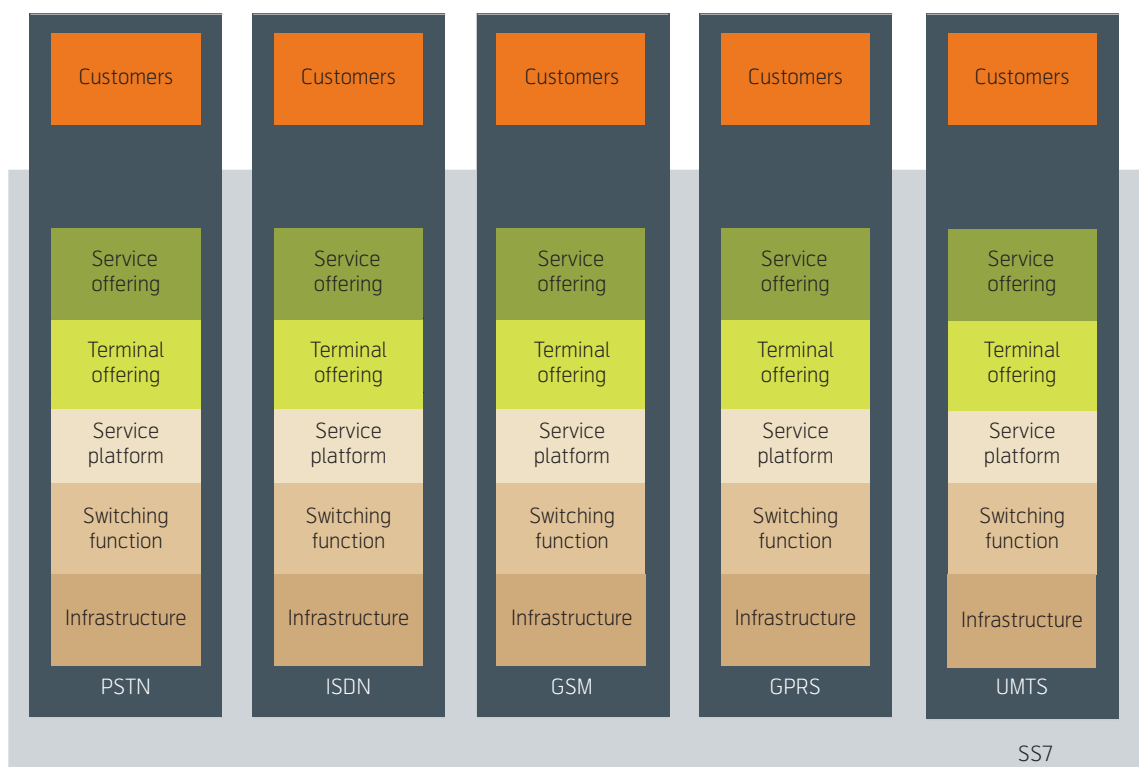


Figure 10 The vertical silos in the telecom world

tem), etc. are typical examples of vertical telecommunication systems that have their own infrastructure and services. It is worth emphasizing that although GPRS and UMTS may share some network elements, they are still complete autonomous systems that can be deployed separately. The telecom world is populated by independent and strongly service-oriented silos which share the signalling network which is the SS7 as shown in Figure 10.

The telecommunication network architecture has definitely very persuasive advantages such as availability, efficiency and reliability which have been proven for many decades. However, things have also changed with time and the drawbacks are getting clearer and clearer. But before shedding light on them it is more logical to glance over to the world of computing.

3 The 'Horizontal' Computer Network

Quite Different Despite Similarities

Today, the usage of digital transmission and transport technologies both in the telecommunication and computer networks has blurred considerably the differences between the two networks and one may even think of them as related to each other. It is worth noting that although the earlier computer networks were using telecommunication network as a means to carry instructions between computers they have completely different origins and were built to serve different purposes and usages than telecommunication networks.

While the telecommunication network is built to connect human beings together, the computer network connects several computers and devices to each other. It allows computers to communicate with each other and share resources and information.

The Advanced Research Projects Agency (ARPA) designed Advanced Research Projects Agency Network (ARPANET) for the United States Department of Defence was the first computer network in the world realised in late 1960s and early 1970s [8][9].

It is obvious that the difference between synchronous telecommunications and asynchronous data services influences the architecture of the computer network. However, more important is probably the role and the architecture of the computer in the architecture network.

The Computer is the Centre, not the Network

In a computer network the entity that plays the central role is the computer, and not the network, as in a telecommunication network. Indeed, it is the com-

puter that carries tasks described by a set of instructions, also called *software program*, *software application* or simply *program* upon request by the users [10]. It is the computer that users are interacting with to get jobs done. A computer can host various programs and the user can request the execution of a particular program by issuing commands to the computer, or nowadays simply by clicking on the icon of the software presented on the desktop, ie. the main screen of the computer. Both the computer and the programs are very much visible to the users. Furthermore, the users may have great influence on the selection, installation and removal of the programs on a computer.

In the computer world, the notion of program or application is central and the notion of service exists only vaguely. Basically, service and application are two aspects of the same issue.

An *application* is a tangible entity, consisting of a set of computer instructions that can be installed in the permanent storage of the computers. While running or executing, an application will provide *services* to the users by performing some tasks for them.

A *service*, on the other hand, is a transient entity that exists only for a period of time, also called *session*, and will vanish upon the termination of the session. It is important to differentiate between the availability and the existence of a service. A service may be available all the time but it only exists upon execution of an application.

Dumb Network and Intelligence at the Edge

In a computer network the intelligence, ie. functions and services, is on the computer and the network is supposed to be dumb and equipped only with the capability of connecting computers together.

Figure 11 depicts a computer network with the intelligence on the computers in the network. The same network can be drawn by moving the same computers to the edge while keeping the cabling between them. A computer network with intelligence at the edge is hence obtained. However, when talking about dumb network [11] or intelligence at the edge [12] people are referring also to the fact that the network operator does not necessarily own the computer offering applications but only the network as such. The intelligence is at the edge of the network and may also be in the hands of third party players.

The Layer Architecture of the Computer

A computer is characterized by two features:

- Automated calculation;
- Programmability.

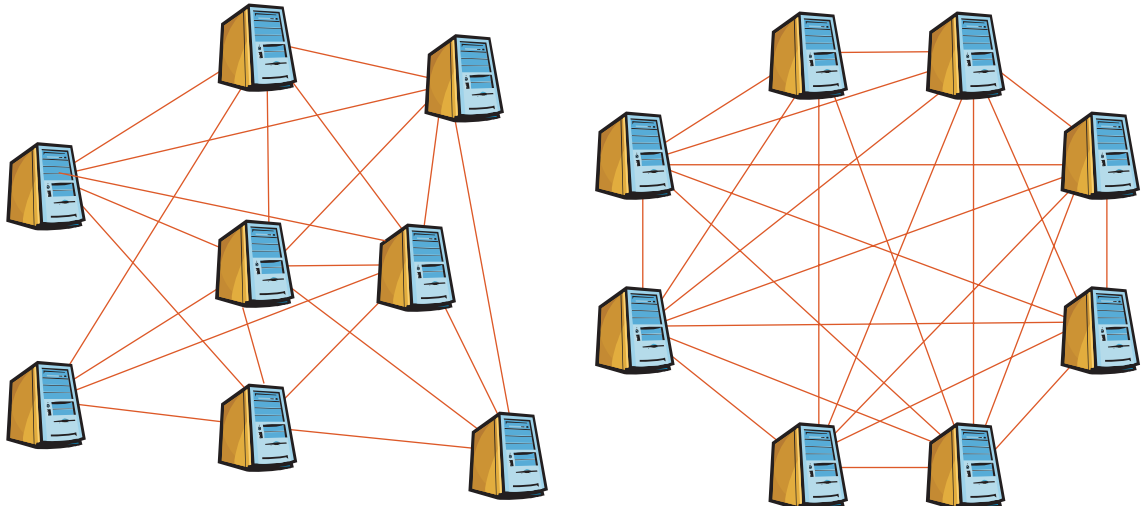


Figure 11 Computer network and Intelligence

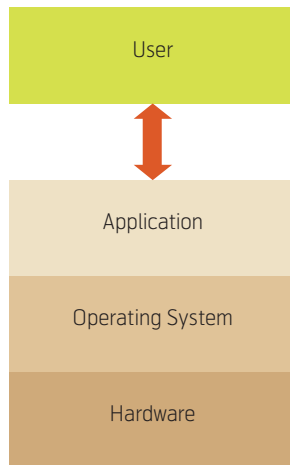


Figure 12 The layered architecture of the computer

Although the first feature is a necessary condition, the defining feature of modern computers which distinguishes them from all other machines, especially calculators, is that they can be programmed. As stated earlier, programmability means that a list of instructions (the program) can be given to the computer and it will store them and carry them out at some time in the future.

The very first computers only supported one program at a time using only a very basic scheduler but it did not take long before every computer was equipped with an operating system enabling multitasking. As shown in Figure 12 an operating system is an interface between hardware and user, which is responsible for the management and coordination of activities and the sharing of the resources of the computer. The operating system acts as a host for software applications executing on the machine. As a host, one of the purposes of an operating system is to handle the details of the operation of the hardware. This relieves soft-

ware programs from having to manage these details and makes it easier to write software applications.

An operating system offers a number of services to application programs and users. Applications access these services through *application programming interfaces* (APIs) or system calls. By invoking these interfaces, the application can request a service from the operating system, pass parameters, and receive the results of the operation. Users may also interact with the operating system using special software called user interface (UI) which could be a command line interface (CLI) or a graphical user interface (GUI).

The layered architecture of the computer focuses on simplifying:

- The development of software programs;
- The installation and execution of software program;
- The independent optimization and upgrading of each layer, eg. hardware, operating system, applications.

The layered architecture of the computer surely has a big influence on the computer network, which naturally has a horizontal architecture. The most recognized abstract model of computer network is the *Open Systems Interconnection Reference Model*, also called *OSI Reference Model* or *OSI Model*. The OSI model is now a standard described in the ITU-T X.200-series of recommendations [5][6].

As shown in Figure 13 the OSI model divides network architecture into seven layers which, from top to bottom, are as follows:

- *Application Layer* is the OSI layer closest to the end user, which means that both the OSI application layer and the user interact directly with the software application.
- *Presentation Layer* establishes a context between Application Layer entities, in which the higher-layer entities can use different syntax and semantics, as long as the Presentation Service understands both and the mapping between them.
- *Session Layer* controls the dialogues (connections) between computers. It establishes, manages and terminates the connections between the local and remote application.
- *Transport Layer* provides transparent transfer of data between end users, providing reliable data transfer services to the upper layers. The Transport Layer controls the reliability of a given link through flow control, segmentation/de-segmentation, and error control.
- *Network Layer* provides the functional and procedural means of transferring variable length data sequences from a source to a destination via one or more networks, while maintaining the quality of service requested by the Transport Layer.
- *Data-Link Layer* provides the functional and procedural means to transfer data between network entities and to detect and possibly correct errors that may occur in the Physical Layer.
- *Physical Layer* defines the electrical and physical specifications for devices.

A *layer* is a collection of conceptually similar functions that provides services to the layer above it and receives services from the layer below it.

On each layer an instance provides services to the instances at the layer above and requests services from the layer below. For example, a layer that provides error-free communications across a network provides the path needed by applications above it, while it calls the next lower layer to send and receive packets that make up the contents of the path. Conceptually, two instances at one layer are connected by a horizontal protocol connection on that layer.

The Universal Network Architecture for Every Service

While the OSI as reference model is only prescriptive the computer network in real life is given by the TCP/IP model. It is a description framework for computer network protocols created in the 1970s by

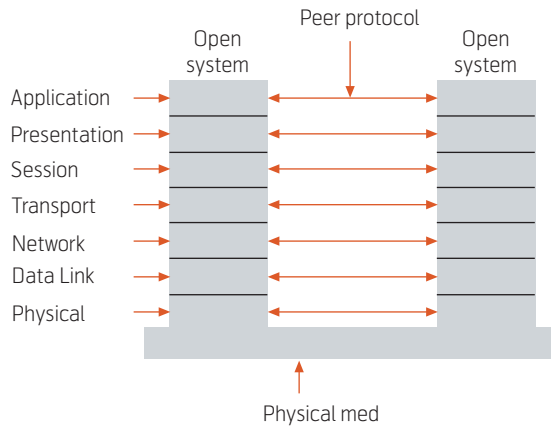


Figure 13 The OSI Reference Model

DARPA, an agency of the United States Department of Defence. It evolved from ARPANET, which was the world's first wide area network and a predecessor of the Internet. The TCP/IP Model is sometimes called the Internet Model.

The *TCP/IP model*, or *Internet Protocol Suite*, describes a set of general design guidelines and implementations of specific networking protocols to enable computers to communicate over a network. TCP/IP provides end-to-end connectivity specifying how data should be formatted, addressed, transmitted, routed and received at the destination. Protocols exist for a variety of different types of communication services between computers.

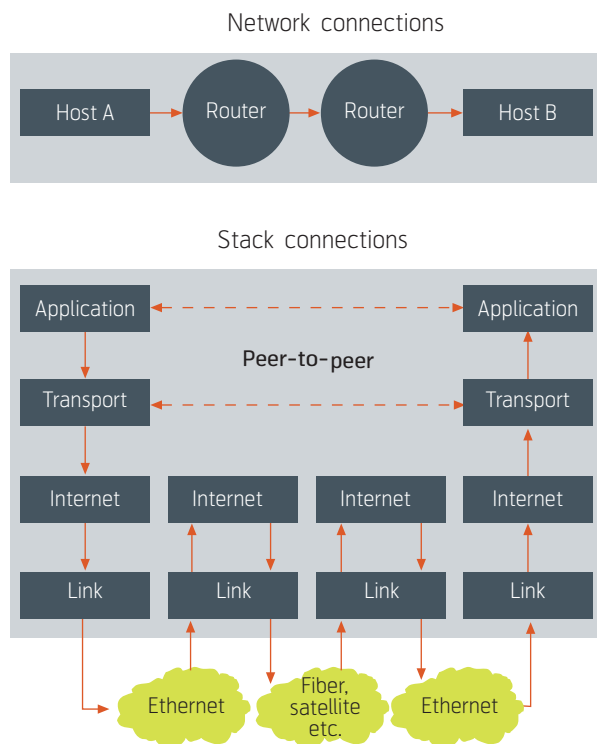


Figure 14 Connection between two Internet hosts via two routers

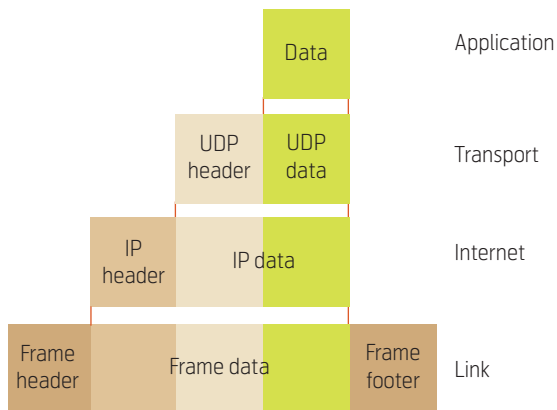


Figure 15 Encapsulation of application data descending through the TCP/IP layers

TCP/IP is a layered model having four abstraction layers [13]:

- *Application (process-to-process) Layer* is the top layer of the Internet protocol suite. The Internet suite does not further subdivide the application layer. Processes or applications on another or the same host, often called peers as shown in Figure 14. Example protocols are SMTP, FTP, SSH, HTTP, etc.
- *Transport (host-to-host) Layer*. The transport layer provides end-to-end services for applications. There are two primary transport layer protocols at present:
 - Transmission Control Protocol (TCP);
 - User Datagram Protocol (UDP).
- *Internet (internetworking) Layer*. The Internet Layer has the task of exchanging datagrams across network boundaries. It is therefore also referred to as the layer that establishes internetworking in order to define and establish the Internet. This layer defines the addressing and routing structures used for the TCP/IP protocol suite. The primary protocol in this scope is the Internet Protocol, which defines IP addresses. Its function in routing is to transport datagrams to the next IP router that has the connectivity to a network closer to the final data destination (see Figure 15).
- *Link Layer*. This layer defines the networking methods with the scope of the local network link on which hosts communicate without intervening routers. This layer describes the protocols used to describe the local network topology and the interfaces needed to affect transmission of Internet Layer datagrams to next-neighbour hosts.

The TCP/IP model and the layered protocol stack design were in use before the OSI model was established and succeeded in winning the battle of standards. Indeed, thanks to its technology characteristics like integrated addressing system, design for routing, underlying network independence, scalability and more importantly its ease of implementation, simplicity of use and openness [14] TCP/IP is today the most popular de-facto industry standard for computer networks, not only for the Internet but also for local area networks, corporate intranets or extranets and home networks.

The popularity of TCP/IP is reflected through the success of the application protocols that use TCP/IP such as the World Wide Web's Hypertext Transfer Protocol (HTTP), the File Transfer Protocol (FTP), Telnet (Telnet) which allows logon to remote computers, and the Simple Mail Transfer Protocol (SMTP). These and other protocols are often packaged in the application layer on the top of TCP/IP protocol to form the Internet Protocol suite.

All over IP – IP over all

The popularity of the TCP/IP protocol suite never stops increasing. More and more applications are emerging and it did not take long before it is tempting to port over all the existing applications and services, including telecommunication services over IP. The vision of All over IP, ie. application convergence on IP and the vision of IP over all, ie. network convergence, is crystallizing.

For telecommunication operators, the economics in terms of CAPEX (Capital Expenditure), OPEX (Operational Expenditures) and long term evolution make the introduction of IP-based network elements very attractive. It is now time to come back and examine the limitations of the telecommunication network.

4 The Transition of Telecommunication Networks to Horizontal Architecture

Demand for Service Flexibility

Although operational and efficient, the telephony met a problem, namely its rigidity or inflexibility. In fact, the tightly integrated vertical architecture does not provide the operator with the ability to customise, ie. to modify and adjust to meet the individual customer's needs. As time goes by and as soon as people get used to the telephone service newer needs started to emerge such as call waiting, call forwarding, calling line identification, etc. These new additional services [15] consist of two types of services:

- *Supplementary services* are centred on the telephony service which is referred to as *basic service* or *basic call* [17]. Examples of supplementary services are:

- CLIP: Calling line identification presentation
- CLIR: Calling line identification restriction
- DDI: Direct dialing-in
- AOC: Advice of charge
- Call waiting
- CFU: Call forwarding unconditional
- CFB: Call forwarding busy
- Barring of Outgoing Calls
- Barring of Incoming Calls
- Multiparty service
- CUG: Closed User Groups
- ECT: Explicit Call Transfer

- *Value-added services* are ‘extra’ services beyond basic service which are offered by the operator for a special fee. Examples of value-added services are:

- Information databases such as stock-exchange quotations, weather, forecasts, etc.
- Telephonist services such as directory inquiry service.

The service logic, ie. program, was hardwired in the switches and operators need to negotiate with the vendors for the development and introduction of new service. The process took two years and was clearly a big problem for operators. Finding a solution to the problem was getting very urgent.

More Intelligence in the Network

In the 1980s, regional Bell operating companies requested for rapid deployment of services in the telephone network. Telcordia Technologies responded to this request by developing the concept of *Intelligent Network 1* [18], [19], [20]. The IN concepts, architecture and protocols were later adopted and developed to standards by the ITU-T. A complete description of the IN emerged in a set of ITU-T standards named Q.1210 to Q.1219, or Capability Set One (CS-1) as they became known.

The idea is simply to separate the service logic from the switching system making the modification and upgrading easier. As shown in Figure 16, the service logic is hosted and executed in the network element called SCP, which is completely separate from the SSP (Service Switching Point).

Actually, the introduction of Intelligent Networks in the 1990s represents the migration towards horizontal architecture. Indeed, the IN architecture can be logi-

cally viewed as a horizontal layer between services and bearer networks such as PSTN, ISDN, B-ISDN, PLMN (Public Land Mobile Network) as shown in Figure 17.

Demand for Simpler but more Powerful Service Creation

Although being a success contributing significantly to the revenue streams both in the fixed and mobile networks [22], as time goes by IN soon started to show weaknesses. An IN service is implemented by combining the so-called Service-Independent building Blocks (SIB), which are the smallest building blocks having well-defined interfaces. Examples of SIBs are Time-dependent selection, Number analysis, Network administration, Communication, etc. The SIBs support only the development of telecommunication services but do not address the needs of computing applications.

The technologies used to implement the SIBs and to compose services are not specified but intentionally left to the vendors for differentiation. This leads to a variety of Service Creation and Execution environments and tools which are different and incompatible. Consequently, the service creation is not as simple as

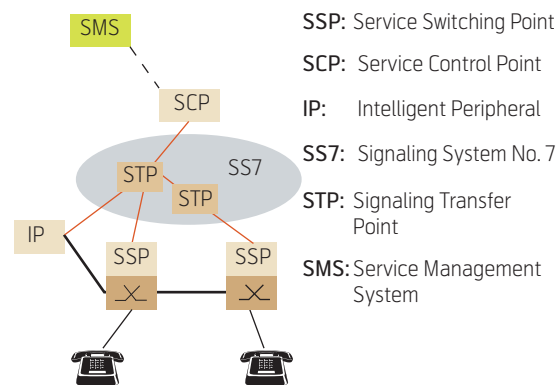


Figure 16 Basic IN architecture

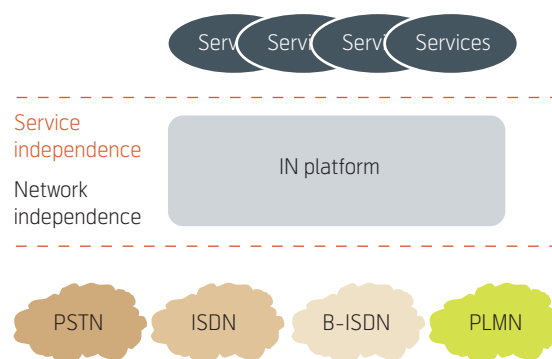


Figure 17 IN as a layer between services and networks

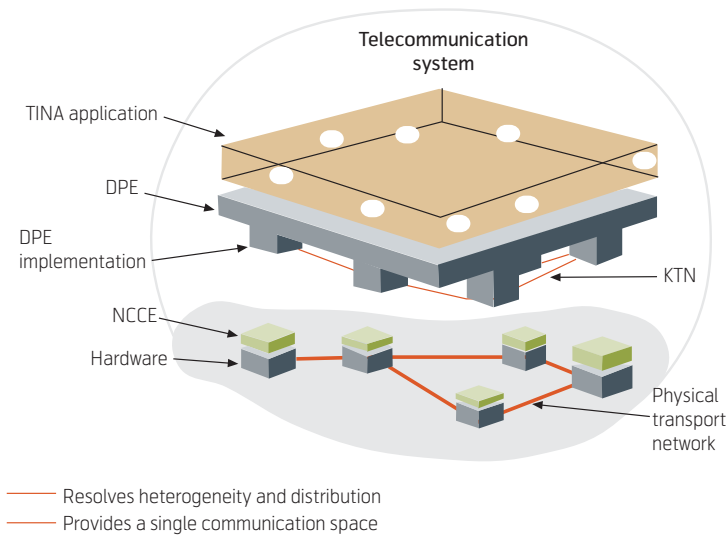


Figure 18 The TINA computing architecture

the development of applications in the computing world at that time.

To meet these challenges in service creation the Telecommunications Information Networking Architecture consortium (TINA-C) [24] consisting of all major telecommunication operators, IT and Telecommunication manufacturers was established in 1993. By the end of 1997, TINA-C had delivered a set of architectural specifications which describe an open service control and management architecture based on a mixture of telecom and computing technologies such as ODP (Open Distributed Processing) [25], [26], [27], IN, TMN (Telecommunication Management Network), CORBA (Common Object Requesting Broker Architecture) [28] and B-ISDN.

As shown, the TINA architecture relies on a Distributed Processing Environment (DPE) which supports TINA applications to be distributed on top of a heterogeneous hardware and software environment. The TINA architecture represents another attempt by

the telecom world to migrate to horizontal architecture. Unfortunately, although having the support of the telecom world TINA never succeeded in attracting the computing world and there was not any commercial implementation and deployment of TINA.

Intelligence Inside the Network is the Hindrance

The main drawback of the service creation in IN may lie in the fact that it remains inside the telecommunication network as well as the created services. This blocks the participation of skilled computer programmers, academics and students to the service creation, which again prevents the blooming of innovative services. It is worth noting that the location and control of the intelligence or service logic has such crucial competitive consequences and the operators are reluctant to let go [23].

To enable third parties to have access to telecommunication network capabilities while letting the operator have the control of the intelligence of the network the Parlay group was initiated in 1998. The objective is to develop open, technology-independent application programming interfaces (APIs) that enable the development of applications that operate across converged networks. The Parlay Open Service Access (OSA) APIs include core network capabilities such as: call control, conferencing, user interaction, user location, charging, etc. As shown in Figure 19 CORBA is used as underlying technology to enable transparent access to remote applications while the authorization is regulated by the OSA framework.

The Parlay/OSA APIs are, however, quite exhausting and demand high telecommunication knowledge. The usage of CORBA as distributed computing middleware was found to be impractical because a tight coupling with the network servers is required.

In 2003 the Parlay Group released a new set of web services called Parlay X which contains a much simpler set of APIs intended to be used by a larger community of developers. The Web service technology is used and improves flexibility and availability. The Parlay X web services include Third Party Call Control (3PCC), Location and simple payment. The Parlay X specifications complement the more complex yet powerful Parlay APIs. Parlay X implementations were deployed as commercial services by BT and Sprint in 2004.

Sneak Invasion of IP

Due to the simplicity and openness of the Internet protocol, the IP-based network elements are becoming more and more affordable compared to the traditional telecom network elements. In addition the

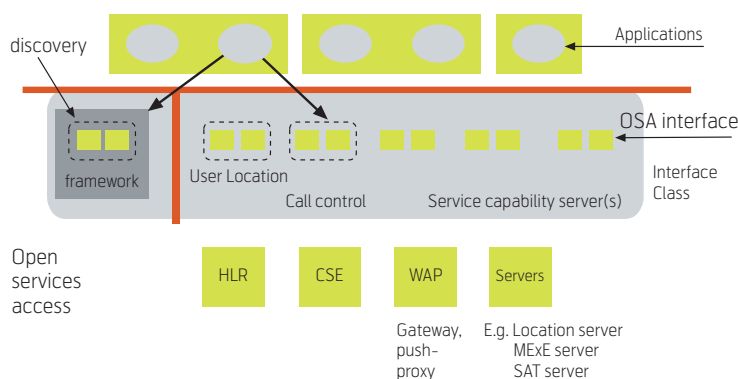


Figure 19 The Parlay/OSA architecture

management and maintenance of IP-based router are also easier and hence more economical. Consequently, several telecom operators started to invest and introduce IP equipment in their networks. Figure 20 shows an example of a mobile backhaul where IP routers are introduced to connect Base Transceiver Stations (BTS) to Base Station Controller (BSC) and Radio Network Controller (RNC).

The Traffic is still on Heterogeneous Networks

The biggest issue for telecom operators remains the heterogeneity of the network silos used in the transportation of traffic eg. PSTN, ISDN, PLMN, etc., which requires high CAPEX and OPEX to operators. The vision of network convergence, ie. a single network for all services was once again revived in full strength. With the increasing popularity of the Internet and the Internet Protocol, it is evident that IP should be the protocol of choice for the future horizontal network capable of accommodating all the services as shown in Figure 21.

5 The Promising Telecommunication Architecture

There are, however, two major issues that slow down the migration to IP. The first problem is the pricing of VoIP, which is usually based on flat rate and not on usage as traditional telephony. New business models are required. The second issue is the capability of supporting voice communication with the same quality, efficiency and reliability as the existing circuit-switched systems, ie. PSTN, GSM, etc.

In fact, Voice over Internet Protocol (VoIP), ie. technologies for delivery of voice communications over IP networks faces the following challenges:

- *Quality of Service.* Because the underlying IP network is inherently unreliable, in contrast to the circuit-switched public telephone network, and does not inherently provide a mechanism to ensure that data packets are delivered in sequential order, or provide Quality of Service (QoS) guarantees, VoIP implementations face problems mitigating latency and jitter.
- *Susceptibility to power failure.* Telephones for traditional residential analogue service are usually connected directly to telephone company phone lines which provide direct current to power most basic analogue handsets independently of locally available power. IP Phones and VoIP telephone adapters connect to routers or cable modems which typically depend on the availability of mains electricity or locally generated power.

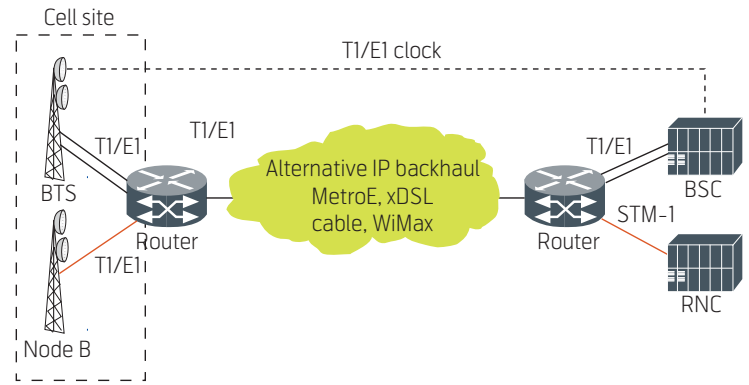


Figure 20 IP Mobile Backhaul

- *Emergency calls.* The nature of IP makes it difficult to locate network users geographically. Emergency calls, therefore, cannot easily be routed to a nearby call centre.
- *Security.* As a computer-based technology, Voice over Internet Protocol telephone systems (VoIP) are as susceptible to attacks as PCs. This means that hackers who know about these vulnerabilities can institute denial-of-service attacks, harvest customer data, record conversations and break into voice mailboxes.

Fortunately, a lot of efforts have been invested and viable solutions to these issues have begun to emerge. Indeed, several VoIP solutions for fixed IP-based networks with quite acceptable quality such as Skype, SIP-based IP telephony, etc. have already been successfully deployed as commercial services. While Skype is based on proprietary protocols, SIP (Session Initiation Protocol) [30] is a standard protocol specified by the Internet Engineering Task Force (IETF).

The IP multimedia subsystem (IMS) [31], [32], which was specified by the 3rd Generation Partnership Project and originally intended to support both syn-

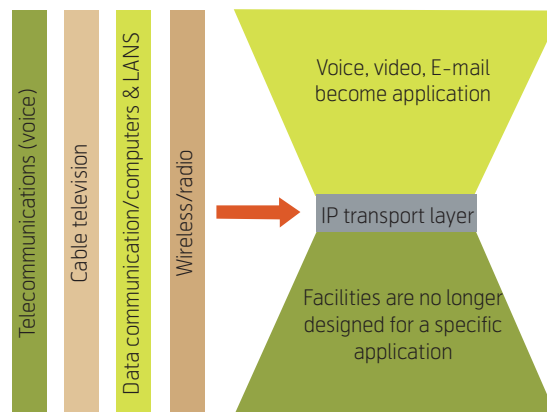


Figure 21 All-IP network for all services

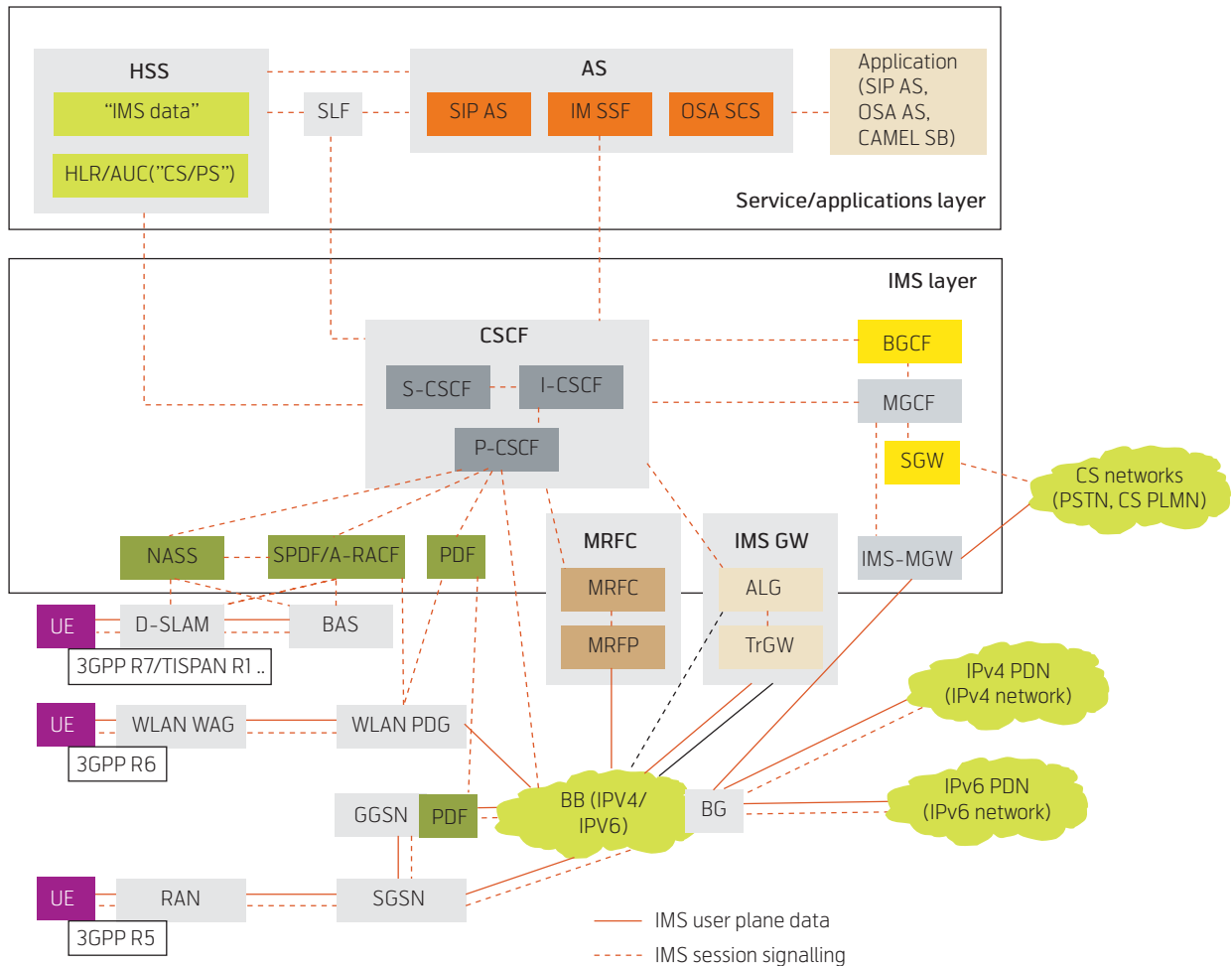


Figure 22 IMS – The emerging all-IP telecom architecture

chronous and asynchronous multimedia applications is now gaining momentum also for fixed networks. In the 3GPP specifications release 7, 3GPP is collaborating with TISPA (Telecoms & Internet converged Services & Protocols for Advanced Networks) to add support for fixed network. The main strength of IMS is its capability of supporting roaming and offering quality of service to mobile users. Most importantly, it allows operators to keep control over network capabilities.

IMS is not intended to standardize applications but rather to aid the access of multimedia and voice applications from wireless and wired terminals, realizing the vision of Fixed Mobile Convergence (FMC). This is done by having a horizontal control layer that isolates the access network from the service layer as shown in Figure 22. From a logical architecture perspective, services need not have their own control functions, as the control layer is a common horizontal layer. Alternative and overlapping technologies for access and provisioning of services across wired and wireless networks include combinations of Generic Access Network, soft switches and native IETF SIP.

IMS got huge support from telecom operators and there are already several deployments in Europe. However, IMS is so far considered only as a natural renewal of the network infrastructure and a way of tying all the heterogeneous networks using an IP-based IMS core. It still remains to be seen whether IMS will succeed as a universal architecture capable of supporting voice services and all other computing services because there other more efficient and more economical alternatives may be emerging from the computing world.

6 Conclusion

In this paper we have studied two originally different networks, namely the telecom network and the computer network, which converged at the arrival of digitalization and advances in technology. With the focus of service efficiency, availability and quality, the telecom network had a vertical architecture while the computer network followed the computer principle of programmability and adopted a horizontal layered architecture allowing flexibility.

Digitalisation in the 1970s made possible the usage of the same technologies in both networks but the real convergence in network architecture did not start before network equipment became abundant. Their price drop enabled over-dimensioning of the network, which consequently made easier the fulfilment of the requirement of efficiency, availability and quality. The focus shift then to flexibility and the vision of a telecom network capable of supporting all services was getting more and more compelling. Unfortunately, both telecom's attempts of introducing a universal network system for all services, ie. ISDN and B-ISDN failed.

There are many reasons for these two failures but one of the most important is the lack of openness of the proposed systems, which are specified as standards for universal networks. Ironically, another protocol suite, TCP/IP, which is originally intended only for computer networks, grew at tremendous speed to become the centre for future layered network architecture. This is due to its two qualities, which are flexibility and simplicity. The telecom world has now embraced the horizontal architecture with IP as the central layer but proposed IMS as the unified architecture for the network of the future. Although IMS has several strengths such as mobility and quality of service, its success is not yet secured and depends very much on the response of the computing world and also the willingness of the telecom world.

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