NGN Functional Architecture for Resource Allocation and Admission Control

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Abstract

A technical prerequisite for a converged network is a common service delivery platform that is independent from the access networks below. The 3GPP SIP-based IP Multimedia Subsystem is defined for this purpose. By specification, IMS is the first implementation towards reaching converged communications which allows users to communicate with video, audio and multimedia content, via any fixed, mobile and wireless access network type, with controllable QoS. This article analyses the mechanisms of resource allocation and admission control by employing logical interfaces that carry SIP messages.

Keywords: *IMS, TISPAN, PSTN emulation, Resource Admission, Metro*

1. Introduction

The concept of Next Generation Network (NGN) provides a new network infrastructure with features and capabilities that support the provision of value-added multimedia services over multiple and heterogeneous QoS enabled transport technologies. In this respect, the ETSI TISPAN group [1] is working on the specification of an NGN based on the IP Multimedia Subsystem (IMS). IMS was introduced in the release 5 of 3GPP standards in 2002, as an IP-based architecture to control of the new value-added services with QoS requirements that were envisioned for UMTS. But, although IMS has conceptually been designed to be independent from the technology used in the access network, the standards developed by the 3GPP are mainly focused on the UMTS IP connectivity access network. From the previous work done by the 3GPP, ETSI and 3GPP started to cooperate in 2004 in the ETSI TISPAN group, in order to define a Core IMS suitable for wireless and wire line networks. TISPAN has published a first release of ETSI IMS standards and is currently working on a second release. We could say that 3GPP describes the point of view of mobile operators (support of new applications), while TISPAN adds the wire line operators specifications (convergence). TISPAN makes specifications for several non IMS subsystems like Network Attachment Subsystem (NASS) and the Resource Admission Control Subsystem (RACS) [2]. Most of the IMS protocols are standardized by the Internet Engineering Task Force (IETF) (e.g. the Session Initiation Protocol (SIP)). Other standardization bodies are involved in the development of IMS. On the other hand, with the rapid development of broadband services, carriers have gradually shifted their focus to broadband AN after expanding and reconstructing the core and service access control layers of MAN. This leads to an analysis of Metro AN (Metro Access Network) technology development. This paper aims at depicting the overall IMS architecture, protocols and technologies of metro access, as well as the related motivation. This paper is divided into seven sections. Basic principles in IP multimedia subsystem is introduces in section 2. Overview of TISPAN NGN is presented in section 3. In section 4, IMS architecture overview is explained. NASS & RACS architecture is analyzed in section 5 and in section 6 PSTN emulation and service architecture is discussed. In the last section access network technologies is explained.

2. Basic principles in IP Multimedia Subsystem

IMS is a converged driver around IP-centric networks for delivering multimedia services from any access technology. One of the basic principles of IMS is Access independence. IMS will eventually work with any network (fixed, mobile or wireless) with packet switching functions such as GPRS, UMTS, CDMA2000, WLAN, WIMAX, DSL and Cable; The older circuit-switched phone system (POTS, GSM) are supported through gateways. Open interfaces between control and service layers allow elements and call/sessions from different access networks to be mixed. The next-generation solutions represent a more efficient to build networks using a common multi-service layered architecture with the capability to simultaneously support multiple service architectures including Class 5 Switches as well as IMS-based SIP application servers and soft switches. The IMS architecture provides for a number of common functions that are generic in their structure and implementation, and can be reused by virtually all services in the network.

2.1. Business and technical motivations

Stepping back, we can see that the IMS standardization comes at an opportune time to exploit a number of technology developments that are already well under way. These include:

• Ubiquitous IP – An underlying IP packet transport network can accommodate different multimedia streams that require substantially different bandwidths. By contrast, the voice telephony network uses a single uniform 64-kbit/s bandwidth for media streams, making it an impractical solution for these new multimedia services.

• Wireless personal terminals –Wireless phones and a plethora of personal devices (such as PDAs, gaming machines, and Black Berry devices) that have had wireless or WLAN communications added to them have changed the telephony model. A wireless phone is a personal phone – people can use it and are reachable wherever they can get coverage. The PSTN, on the other hand, is not designed to exploit the opportunities for personalization that this development provides.

• Affordable terminal displays –Today's end devices (such as cell phones, Black Berry devices, and PDAs) have not only powerful processing capabilities but also graphical display screens to enable features and applications, such as presence and location, that are impossible to provide using the man machine interface of a POTS phone.

3. TISPAN architecture overview

Figure 1 shows a simplified overview of the functional architecture of TISPAN NGN release 1. This functional architecture is covered in detail in [1].

As it indicated in the figure, the architecture is structured in two layers, the transport layer and the service layer, that are built up by a set of subsystems and functional entities. The transport layer provides IP connectivity to the user equipment in client premises. The functionality supported by this layer is in turn divided in two sub layers, a transport control sub layer and a transfer sub layer.

A Transport layer consisting of the user equipment (UE), Access Network, NGN core, NASS (see section3.4) and RACS (see section 3.5). The service layer is composed of the following components:

• The IP Multimedia subsystem core components.
• The PSTN/ISDN Emulation Subsystem (PES).
• Other multimedia subsystems (e.g. streaming, content broadcasting etc.) and applications.
• Common components used by several subsystems such as those required for accessing applications, charging functions, user profile management, security management, routing databases etc.

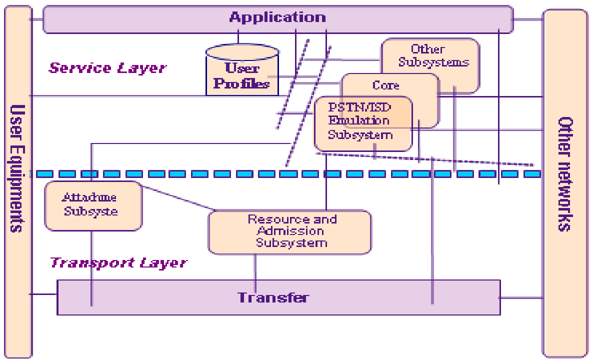

Figure1.Overview of the functional architecture of TISPAN NGN release 1.

Regarding QoS provision mechanisms, in the transport control sub layer the most relevant component is the Resource and Admission Control Subsystem (RACS). This subsystem performs policy control, resource reservation and admission control functions in the NGN. The RACS subsystem provides applications with the capability of reserving resources from the transport networks, guaranteeing QoS provision for the value-added services in the NGN. Further details can be found in [2]. On the other hand, the functional entities that constitute the transfer sub layer are covered in detail in [1]. The service layer comprises a set of subsystems that provide service control functionalities. Among them, the Core IMS [3], provides the means to negotiate SIP-based multimedia services to NGN terminals. It is a subset of the IMS as it was defined in the 3GPP Release 6 specifications, restricted to the session control functionalities. Finally, the service layer also provides a set of common components. One of these components is the Application Server Function (ASF). The functionality of the ASF in the NGN architecture consists of providing value-added services to the NGN terminals.

4. IMS architecture overview

When broken down to its bare essentials, the role of IMS is to provide a secure and reliable means for terminals and applications to reach, negotiate and communicate with each other. This facilitates for the operator to provide multiple services to the user and maximizing equipment reuse through horizontalization. The horizontalization provides common; supervision and control of services in the IMS network, management and routing of sessions, as well as supporting the authorization and manipulation of media in the network. The IMS core is access independent which means that same services can be delivered over different types of access technologies. In the IMS specification the “core” of IMS comprises two main nodes: the Call Session Control Function (CSCF) and the Home Subscriber Server (HSS). In the IMS architecture overview (Figure 2 below) the General Switched Telephony Network (GSTN) inter-working functions Media Gateway Control Function (MGCF) and Media Gateway (MGW) have been depicted beside the IMS Core [3,8,9]. The Call Session Control function (CSCF) is the heart of the IMS architecture and is used to process SIP signaling. The main function of the CSCF is to provide session control for terminals and applications using the IMS network. Session control includes the secure routing of the SIP messages, subsequent monitoring of the SIP sessions and communicating with the policy architecture to support media authorization. It has also the responsibility for interacting with the HSS. It can play three different roles: Serving-, Interrogating and Proxy- Call Session Control Function (S-, I- and P-CSCF). The Home Subscriber Server (HSS) is the master database that contains user and subscriber information to support the network entities handling calls and sessions. It provides the following functions: identification handling, access authorization, authentication, mobility management (keeping track of which session control entity is serving the user), session establishment support, service provisioning support, and service authorization support.

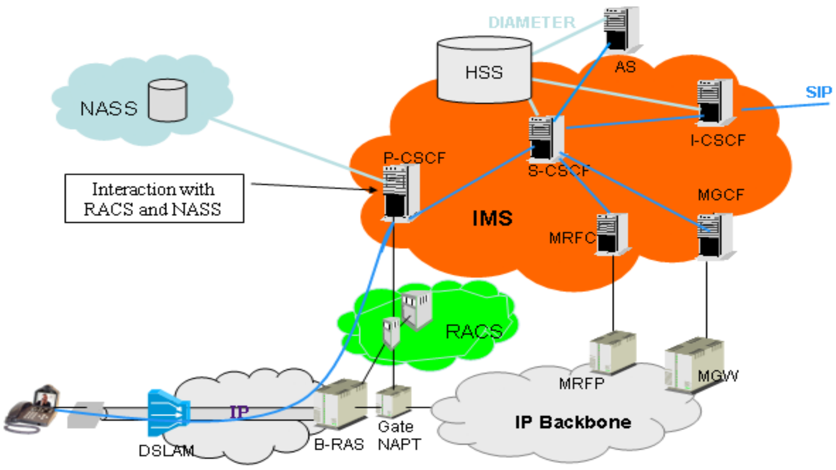

Figure2. IMS architecture overview

When a user registers in the IMS domain, the user profile (relevant information related to the services to be provided to the user) is downloaded from the HSS to the CSCF. For session establishment, HSS provides information on which CSCF currently serves the user. When more than one HSS is deployed in the network, a Subscriber Location Function (SLF) is needed to locate the HSS that holds the subscription data for a given user. Both the HSS and SLF use Diameter.
SIP is the main signaling protocol used in IMS networks. It was developed by the IETF and was selected by 3GPP as a standard for IMS in Release 5. The function of SIP is to establish, modify and terminate multimedia sessions (with medias such as voice, video and chat) over IP networks, where the media delivery part is handled separately. In SIP there is just one single protocol, which works end-to-end and supports the establishment and termination of user location, user availability, user capability, session set-up and session management. SIP is also designed to enable additional multimedia sessions and participants to be dynamically added or removed from a session. These are the major reasons SIP has been selected in IMS; it is also considered to be flexible and secure. Diameter is the Authentication, Authorization, and Accounting protocol. Diameter is a development of the current RADIUS protocol, was chosen as the policy support and Accounting, Authentication, Authorization (AAA) protocol for IMS. Diameter is used by the S-CSCF, I-CSCF and the SIP application servers in the Service Layer, and in their exchanges with the HSS containing the user and subscriber information. Compared with RADIUS, Diameter has improved transport – it uses Transmission Control Protocol (TCP) or Stream Control Transmission Protocol (SCTP), and not UDP, as transport – improved proxy, enhanced session control and higher security. H.248 is a control protocol used between media control functions and media resources. Examples of nodes with media control functions are the Media Gateway Control Function (MGCF) and Media Resource Function Controller (MRFC). Typical media resources are the Media Gateway and Media

Resource Function Processor (MRFP). Internet Protocol version 6 (IPv6) is a network-layer IP standard used by devices to exchange data across a packet-switched network. It follows IPv4 as the second version of the Internet Protocol to be formally adopted for general use. Originally, IMS was specified to use IPv6; however, with 3GPP Release 6, IMS does provide support for IPv4 and private address scheme. This means that even though IMS is expected to drive the adoption of IPv6, it is not dependent on IPv6 availability in order to be successfully launched.

5. NASS & RACS architecture

5.1. Network Attachment Subsystem

This module provides registration and (potentially) initialization of user equipment so that the subscriber can access the services provided in the Service Layer. From a network perspective, NASS provides network-level identification and authentication. This module is also responsible for managing the IP address space within the Access Network and providing authentication to service sessions. Network attachment is provided based on either implicit or explicit user identification credentials stored in its database (respectively, physical or logical Layer 2 addresses, or user name and password) (see Figure 3). This subsystem provides five essential functions3:

- Dynamic provisioning of IP addresses and other terminal-configuration parameters
- Authentication at the IP layer prior to or during the address-allocation procedure
- Authorization of network access based on user profiles
- Access network configuration based on user profiles
- Location management at the IP layer

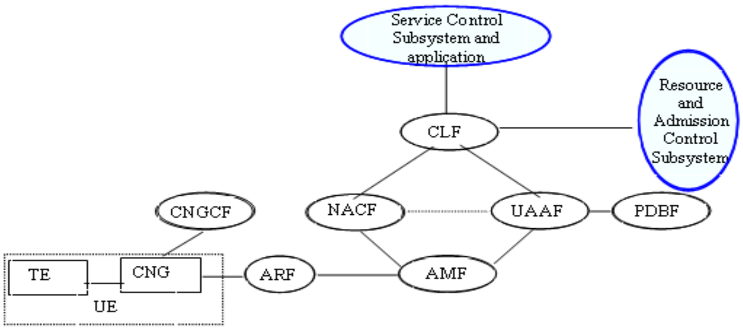

Figure3. ETSI TISPAN NASS Architecture

5.2. Resource and Admission Control Subsystem

The Resource and Admission Control Subsystem (RACS) arbitrates between service control functions (SCF) and transport functions for QoS related transport resource control within access and core networks. The RACS performs the policy based transport resource control upon the request of the SCF, determines the transport resource availability and admission, and applies controls to the transport functions to enforce the policy decision, including resource reservation, admission control and gate control, NAPT (Network Address and Port Translation) traversal, and firewall control. It interacts with transport functions to control the following functions in the transport layer: bandwidth reservation and allocation, packet filtering; traffic classification, policing, priority handling; network address and port translation; firewall. This way, the RACS ensures that service layer entities do not need to be concerned with details related with transport networks, like the network topology and transmission technologies. The RACS is the most important logical network element for the interaction between the service layer and the transfer functions for resource control and QoS support within the respective NGN (see Figure 4). RACS can be divided into two functional blocks: the Serving Policy Decision Function (S-PDF) and the Access Resource and Admission Control Function (A-RACF), as described in [4]. The A-RACF and the SPDF perform similar functions, such as making bandwidth management decisions, but they do this at different points in the network. An A-RACF would typically be assigned to a specific access network, while an SPDF would interact with one or multiple A-RACFs. The A-RACF and the SPDF interact using the Diameter protocol, which is an AAA (authentication, authorization, and accounting) protocol defined by the IETF. The SPDF, in turn, interacts with a Policy Enforcement Point (PEP) in the underlying core network via a profile of H.248, the media gateway controller signaling protocol defined jointly by the ITU-T and the IETF. In the core network, this PEP could be, for instance, a border gateway function. In the access network, the A-RACF interacts with PEPs located in the underlying access (and metro) networks, such as access nodes and IP edge routers, via the Ra and Re reference points. The basic RACS functionalities in TISPAN NGN are indicated below:

• Policy Control. The RACS subsystem applies to resource reservation requests a set of policy rules to check if these requests can be authorized and to determine how must they be served. Policy control is also performed in the access network, applying network policies specific to each particular access line.

• Admission Control. The RACS subsystem verifies if the requested QoS demands can be satisfied with the resources that are available in the involved access network.

• Resource reservation. The RACS subsystem provides the means to reserve bearer resources on the access network.

• NAT/Gate Control. The RACS subsystem controls NAT functionalities and performs gate control functions, at the limit between the access and core networks and in the limit between core networks [2,5].

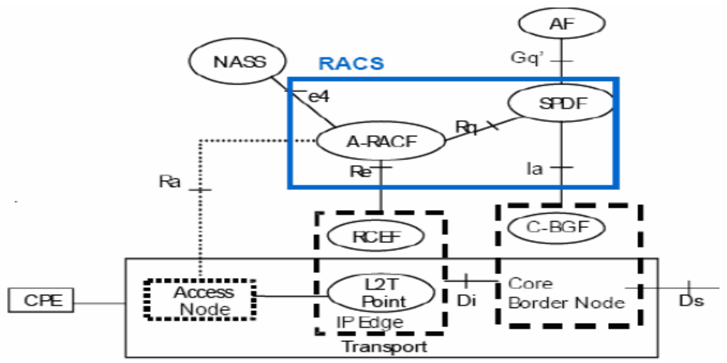

Figure4. TISPAN RACS architecture

5.3. RACS & NASS corporation

To better understand how the various components of the RACS architecture work together, the following example is a walk-through of a RACS session. Prior to any interaction with services (such as IMS), an IP connection must first be established. To obtain an IP pipe, the user connects to the network through another subsystem called the Network Attachment Subsystem (NASS), which is responsible for authentication and authorization of the subscriber to the access network. The NASS also provides the IP address and binds this IP address with such parameters as a line identifier, which identifies the access type. Once attached to the access network, the NASS uploads a set of static policy parameters to the A-RACF in the RACS. These static policy parameters are derived from the user network profile, which is stored in the profile database in the access network. Static policy parameters may include such items as the maximum bandwidth that the access line can support. At this point, the user can begin to interact with the services. To do this, some application signaling will take place between the user and an Application Function (AF) in order to register the user with the application. When a user starts to use a service (e.g., through the initiation of a SIP INVITE to a CSCF in the case of an IMS service), it is at this point that the AF begins to interact with the RACS – specifically to communicate the bandwidth and potentially other resource control requirements to the SPDF. Note that the AF discovers which SPDF to talk to either by querying the NASS – specifically the Connectivity Session Location Function (CLF) – to obtain the IP address or Fully Qualified Domain Name (FQDN) of the SPDF, or via some other means, such as static configuration (see Figure 2,3,4). The SPDF then applies policies (which may include simple rules such as “is this application allowed to make this request for network resources?”) and, if appropriate, initiates a command to the BGF to enforce particular traffic policies. The SPDF may also initiate a further resource request to the A-RACF to request reservation of resources in the access network. This subsequent request may result (after application of policy at the A-RACF) in a command to the IP edge router to apply a particular traffic policy. Note that RACS Release 1 does not specify a protocol for the interface between the A-RACF and the IP edge router, although limited stage-2 guidance is Provided in ES282003. Given that it acts as the fulcrum for policy-based resource control in the network, the SPDF also supports the coordination of resource control requests/responses for a particular RACS session. For example, the SPDF may wait for a response from the A-RACF as to whether or not resources can be assigned before replying to the AF with the overall status of all resources that have been assigned [2,6,7].

6. PSTN emulation and service architecture

Figure 5 shows the PSTN/ISDN Emulation Subsystem and its relationships with other TISPAN NGN subsystem. The service architecture for the PES and the IMS subsystems is the same. The generic behavior of a application server functions is identical with respect to the PSTN/ISDN Emulation Subsystem and the TISPAN IMS. However, depending on the type of services to be emulated, certain application servers may need to understand and terminate the ISUP protocol encapsulated in SIP. Three types of Application Server Functions (ASF) can be accessed by the IMS-based PES, through the ISC or Ma reference point (see figure 5).

- SIP Application Servers (SIP AS).
- The IM-SSF Application Server.
- The OSA SCS Application Server.

A SIP Application Server may contain "Service Capability Interaction Manager" (SCIM) functionality and other application servers. The SCIM functionality is an application which performs the role of interaction management. The internal structure of the application server is outside the standards. The purpose of the IM SSF is to enable access to IN service logic programs hosted in legacy SCPs. The IM-SSF functionality encompasses the emulation of the IN Call Model (BCSM) on top of SIP signaling, IN triggering and feature management mechanisms, emulation of the IN Service Switching Finite State Machine and inter-working with INAP. The role of the IM-SSF is identical in the PSTN/ISDN Emulation Subsystem and in the IMS subsystem ES 282 007 [3]. Basic behavior is also identical. However, in the PES case, mapping procedures may take into account ISUP information encapsulated in SIP messages. The IM SSF is intended to enable access from the PES to IN service logic programs hosted in legacy SCPs. Access to PES services (i.e. hosted in SIP-based Application Servers) from legacy SSPs in the PSTN/ISDN is outside the scope of the present document. Appropriate gateway functions (e.g. SPIRITS gateway as defined in RFC 3136 [10] have to be implemented in the PSTN/ISDN network for supporting such scenarios. The purpose of the OSA Service Capability Server is to provide access to OSA applications, according to the OSA/Parlay framework ES 201 915-1 [11]. The Service-CSCF to AS interface is used to forward SIP requests, based on filter criteria associated with the originating or destination user. The Interrogating-CSCF to AS interface is used to forward SIP requests destined to a Public Service Identity hosted by the AS directly to that AS. The procedures between AGCF and AS (using reference points Mw, Mx, Ic and ISC) shall be standard and open to allow for interoperability of equipment from different vendors which may be located in different networks.

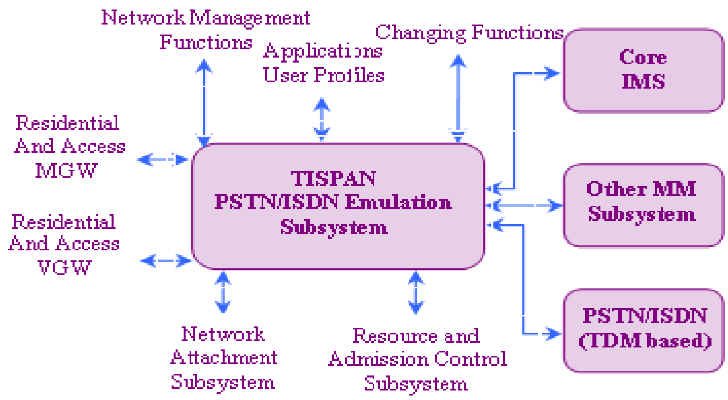

Figure5. PSTN/ISDN Emulation Subsystem and its environment

The range of services that can be emulated in TISPAN NGN Release 1 is constrained by the functional architecture and the IMS SIP profile defined in ES 283 003 [12]. The e2 reference point supports information transfer between the P-CSCF or the AGCF and the Network Attachment Subsystem. The role of this reference point with respect to the PSTN/ISDN Emulation Subsystem and the IMS subsystem is identical. Interaction with the NASS is not be required in case the AGCF controls access gateways only. The Gq' reference point enables the P-CSCF or the AGCF to interact with the resource control subsystem for the following purposes:

- Authorization of QoS resources;
- Resource reservation;
- Gate control (including NAPT binding information relay)

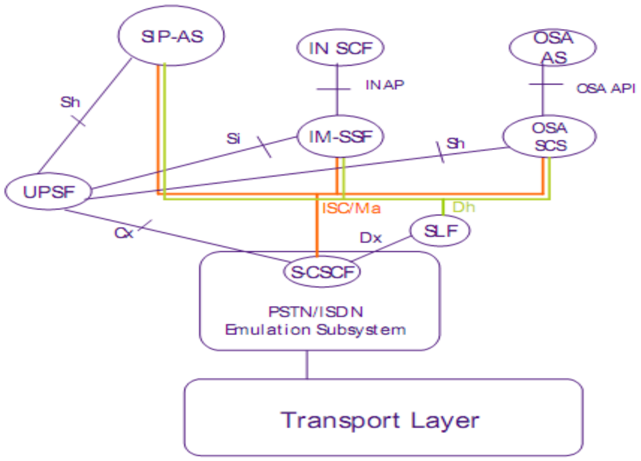

Figure6.Value added services architecture

With regard to the RACS architecture; the P-CSCF and the AGCF play the role of an Application Function (AF). The role of this reference point with respect to the PSTN/ISDN Emulation Subsystem and the IMS subsystem is identical. Interaction with the NASS may not be required in case the AGCF controls access gateways only and dedicated transport resources are used to support PES traffic.

7. Metro access NGN technologies

The broadband AN is the last-mile access to end users and it is being challenged by broadband acceleration and multi-service bearing as these features require a shorter distance from DSLAM to users. For this reason, the location of DSLAM is constantly lowered, while the BRAS/SR locations remain unchanged which results in greater space in the Metro AN. As IP-based MAN will bear IPTV and NGN services, the demands are high on bandwidth, security, reliability and QoS [15]. Indeed, traditional Ethernet can hardly adapt to meet them. With the purpose of a rapidly developing Metro AN, various international standardization organizations have proposed applicable technical standards. IEEE launched Ethernet technology-based SVLAN (Super VLAN), RPR (Resilient Packet Ring) and PBB (Provider Backbone Bridge), while IETF has been developing and optimizing MPLS (Multi-Protocol Label Switching) technology. Equipment suppliers in turn have been developing and promoting different solutions. Switch vendors favor SVLAN and Ethernet ring technology; router vendors promote “MPLS extended to edge”; and optical network equipment vendors prefer RPR. Carriers have also been selecting technologies and solutions. Many traditional carriers favor MPLS extension, whereas new carriers tend to opt for Ethernet enhancement. Some carriers, such as BT, prefer PBT solution. It is clearly worthwhile to analyze and compare these Metro AN technologies. Based on traditional Ethernet and VLAN, various new technologies have been developed for Metro AN including Ethernet enhanced technologies (SVLAN, PBB/PBT and V-Switch), transport technology-based RPR, and PWE2 and VPLS which are based on Ethernet and MPLS integration. Each of these technologies possesses different features.

8. Conclusion

As discussed in previous sections, IMS opens up new perspectives for network operators. But several technical and business challenges have to be faced in order to enable the wide adoption of this promising technology. IMS has the tools and functions necessary to handle numerous of non-standardized services in a standardized way: interoperability; access-awareness; policy support; quality of service; inter-working with existing networks; the properties necessary to meet ever-increasing consumer demand for attractive and convenient offerings.

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