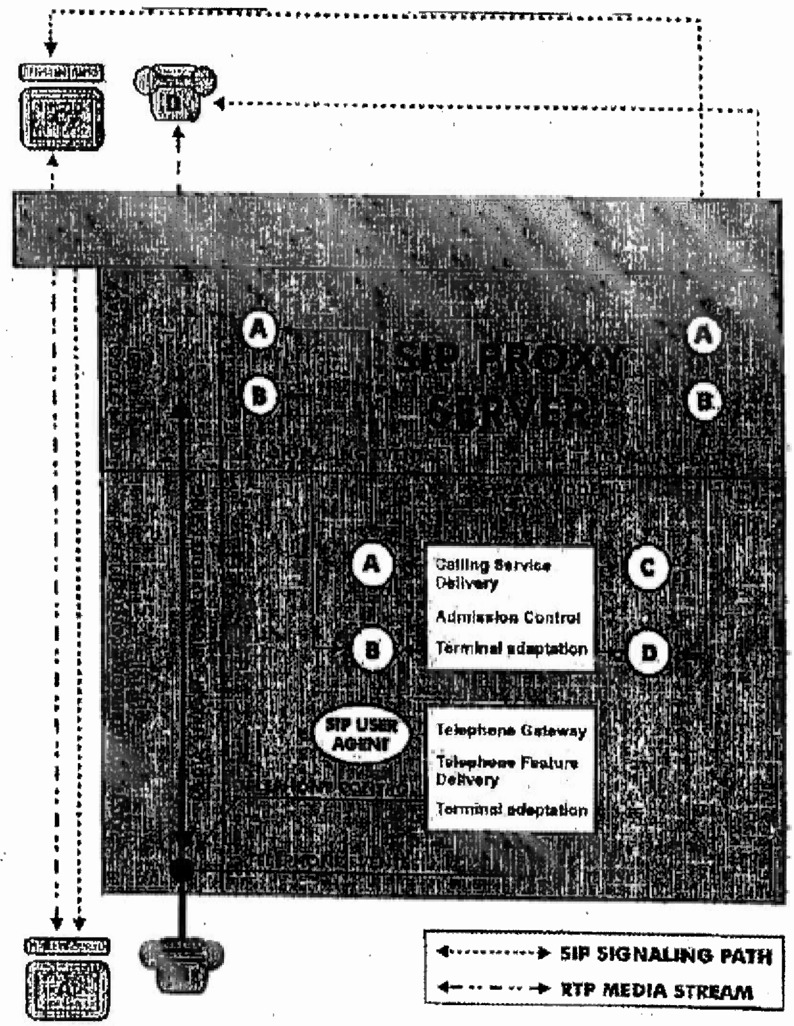
SIP PROXY SERVER
A
B
A
B
A
Calling Service Delivery
Admission Control
Terminal adaptation
C
B
D
SIP USER AGENT
Telephone Gateway
Telephone Feature Delivery
Terminal adaptation
SIP SIGNALING PATH
RTP MEDIA STREAM

FIGURE 7

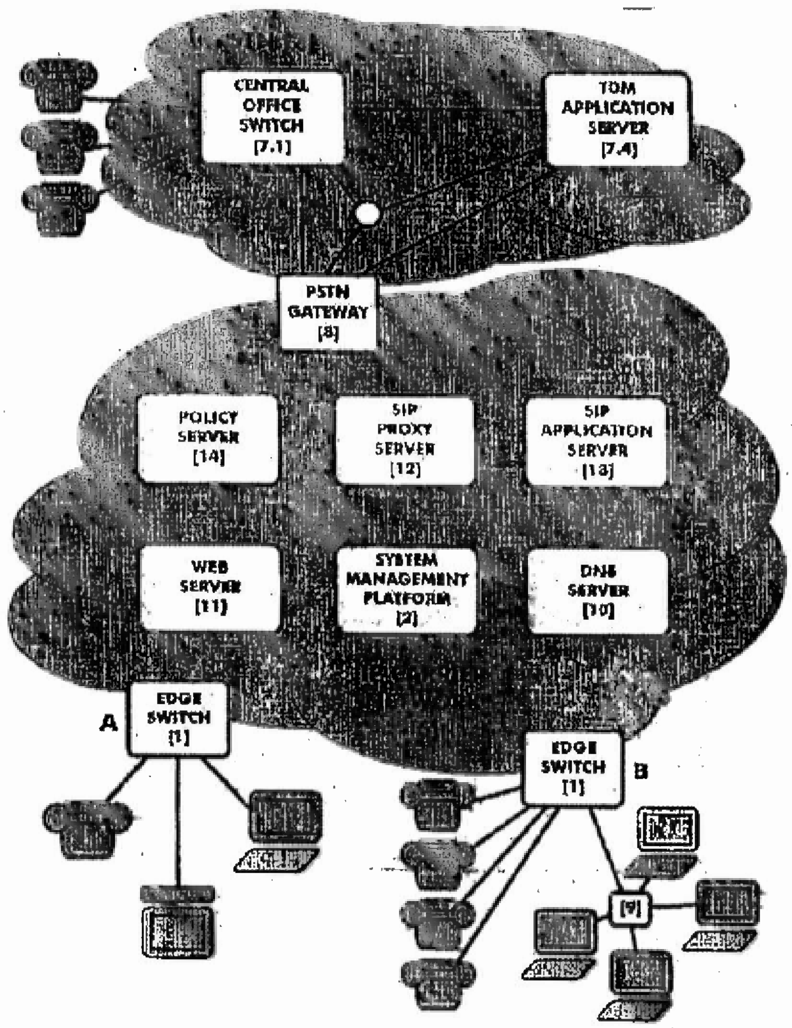
CENTRAL OFFICE SWITCH [7.1]
TDM APPLICATION SERVER [7.4]
PSTN GATEWAY [8]
POLICY SERVER [14]
SIP PROXY SERVER [12]
SIP APPLICATION SERVER [13]
WEB SERVER [11]
SYSTEM MANAGEMENT PLATFORM [2]
DNS SERVER [10]
A
EDGE SWITCH [1]
EDGE SWITCH [1]
B
[9]

FIGURE 8

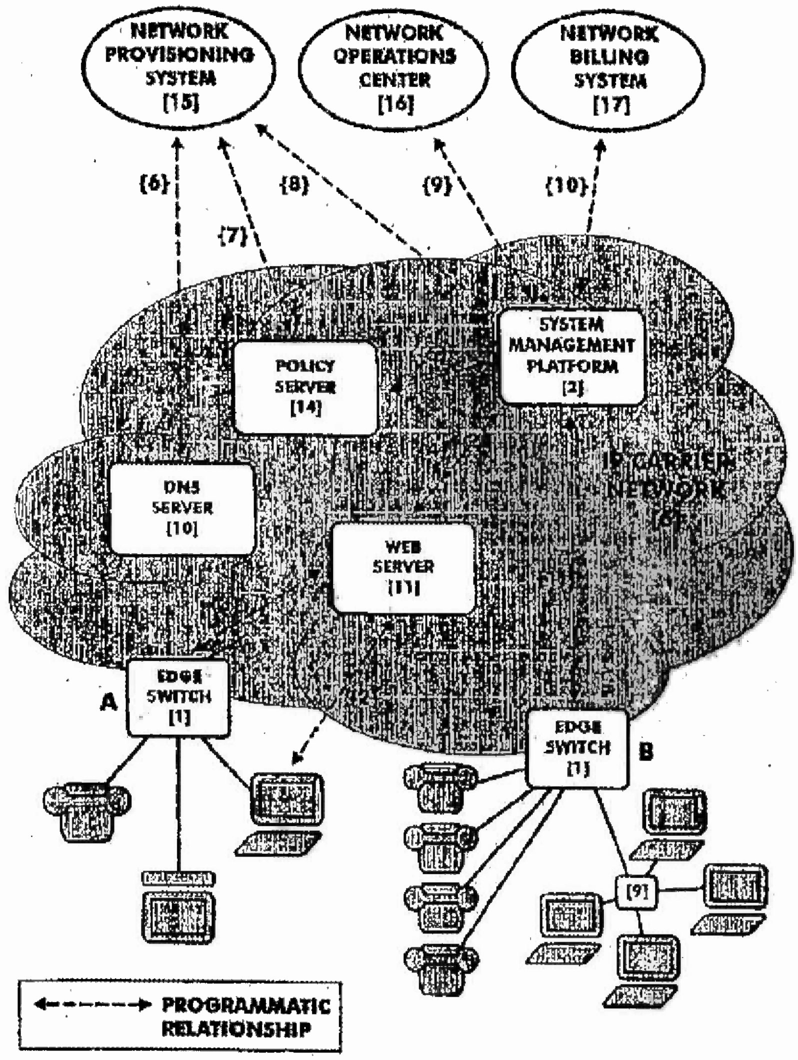
NETWORK PROVISIONING SYSTEM [15]
NETWORK OPERATIONS CENTER [16]
NETWORK BILLING SYSTEM [17]
{6}
{7}
{8}
{9}
{10}
POLICY SERVER [14]
SYSTEM MANAGEMENT PLATFORM [2]
DNS SERVER [10]
WEB SERVER [11]
EDGE SWITCH [1]
A
EDGE SWITCH [1]
B
[9]
PROGRAMMATIC RELATIONSHIP

FIGURE 9

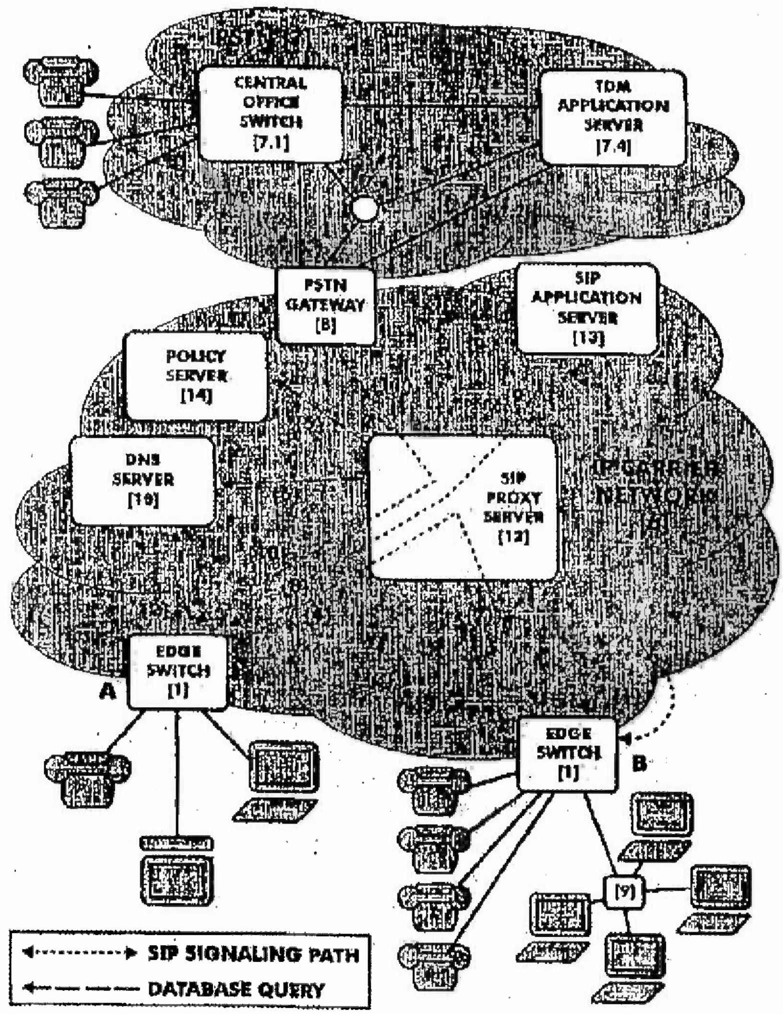
CENTRAL OFFICE SWITCH [7.1]
TDM APPLICATION SERVER [7.4]
PSTN GATEWAY [8]
SIP APPLICATION SERVER [13]
POLICY SERVER [14]
DNS SERVER [10]
SIP PROXY SERVER [12]
IP CARRIER NETWORK
EDGE SWITCH [1]
A
EDGE SWITCH [1]
B
[9]
SIP SIGNALING PATH
DATABASE QUERY

FIGURE 10

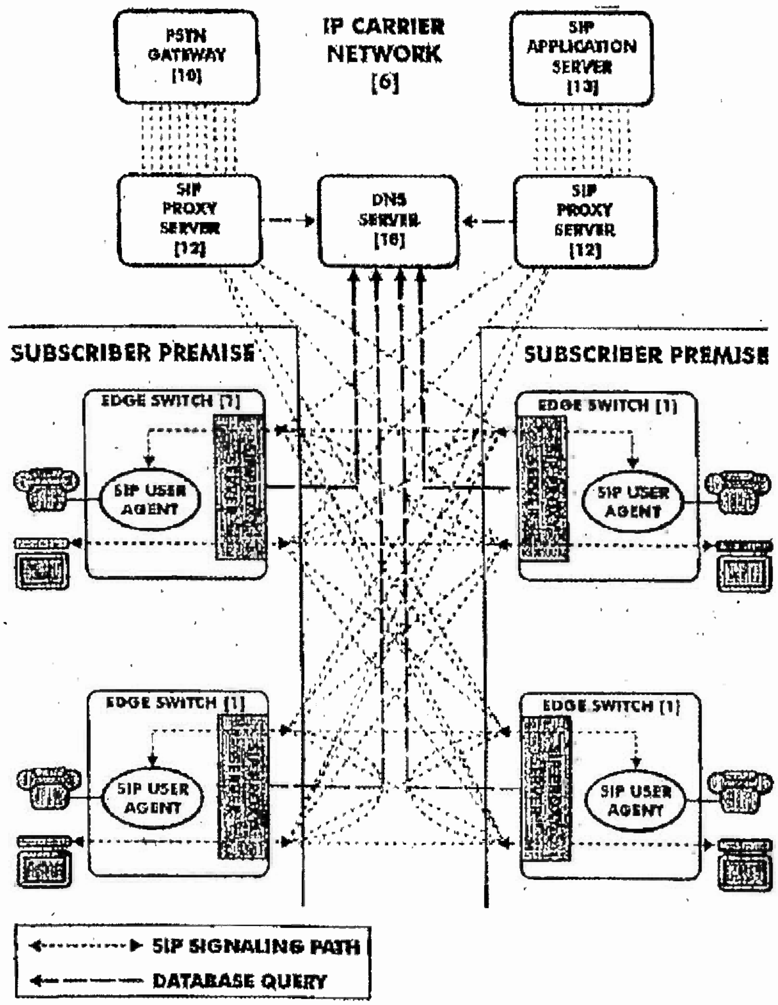
PSTN GATEWAY [10]
IP CARRIER NETWORK [6]
SIP APPLICATION SERVER [13]
SIP PROXY SERVER [12]
DNS SERVER [16]
SIP PROXY SERVER [12]
SUBSCRIBER PREMISE
SUBSCRIBER PREMISE
EDGE SWITCH [1]
SIP USER AGENT
EDGE SWITCH [1]
SIP USER AGENT
EDGE SWITCH [1]
SIP USER AGENT
EDGE SWITCH [1]
SIP USER AGENT
SIP SIGNALING PATH
DATABASE QUERY

FIGURE 11

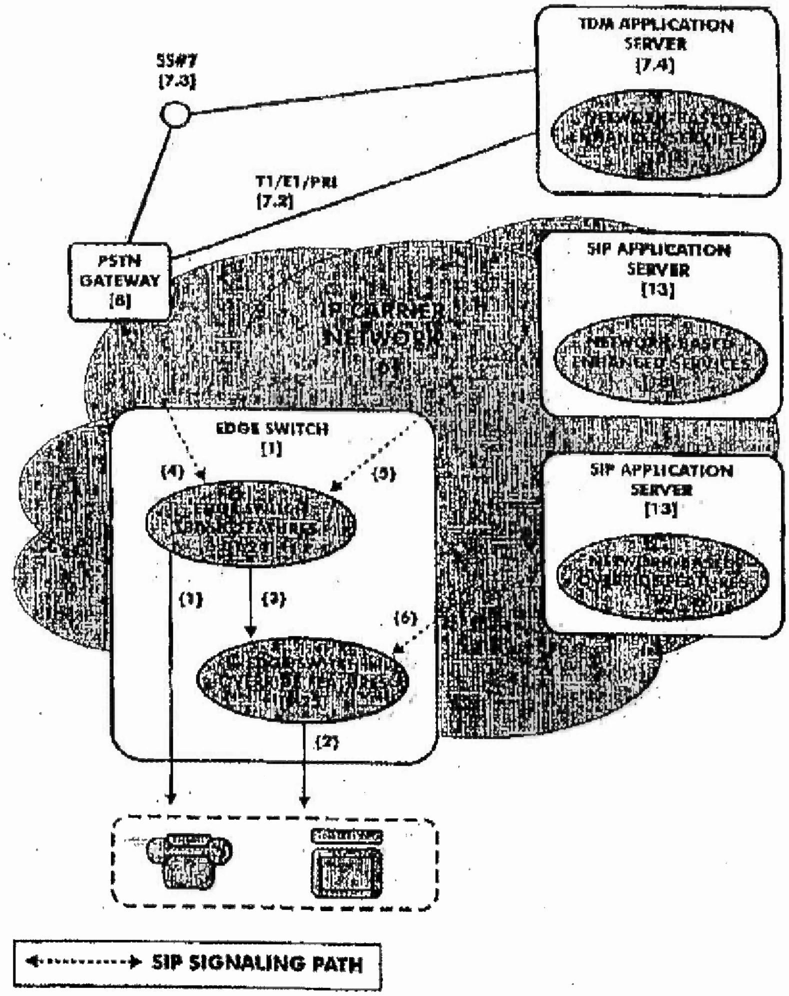
TDM APPLICATION SERVER [7.4]
SS#7 [7.3]
T1/E1/PRI [7.2]
PSTN GATEWAY [8]
SIP APPLICATION SERVER [13]
EDGE SWITCH [1]
(4)
(5)
(1)
(3)
(6)
(2)
SIP APPLICATION SERVER [13]
SIP SIGNALING PATH

FIGURE 12

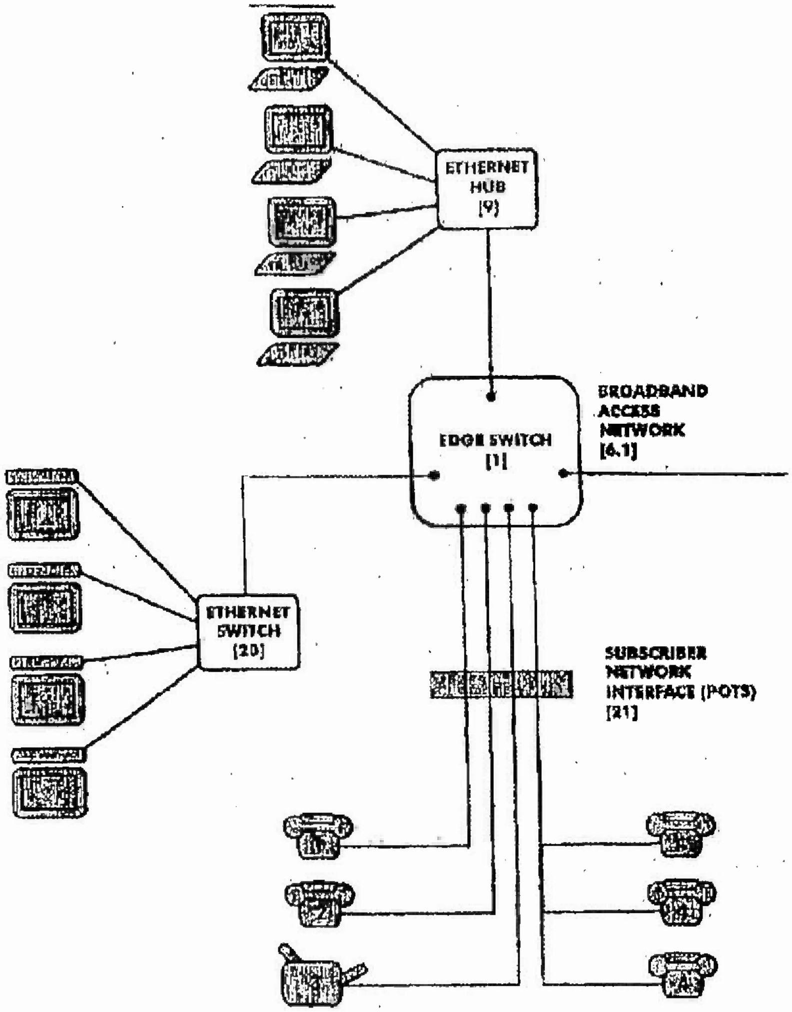
ETHERNET HUB [9]
EDGE SWITCH [1]
BROADBAND ACCESS NETWORK [6.1]
ETHERNET SWITCH [20]
SUBSCRIBER NETWORK INTERFACE (POTS) [21]

FIGURE 13

DISTRIBUTED EDGE SWITCHING SYSTEM FOR VOICE-OVER-PACKET MULTISERVICE NETWORK

RELATED APPLICATION

[0001] This application claims priority to U.S. provisional application 60/283,888 filed on Apr. 13, 2001, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] This invention relates to packet networks, and more particularly to network devices.

BACKGROUND

[0003] This section contains a discussion of background. It summarizes telecommunications carrier network architectures that currently exist as legacy or that are currently under development. It also includes discussion of insights and observations made by the inventor about the prior art systems that are helpful to understanding the subsequently described invention but that were not necessarily appreciated by persons skilled in the art or disclosed in the prior art. Thus, the inclusion of these insights and observations in this background section should not be interpreted as an indication that such insights and observations were part of the prior art. After the background discussion, a new Edge Switched Network (ESN) architecture is introduced and it is described and compared to leading "Next Generation Network" alternatives. A Distributed Edge Switch (DES) makes possible the implementation of an ESN. In the OVERVIEW section that is found in the Detailed Description section, the design, operation and management of the DES are described within the architectural context provided by the ESN.

Next Generation Networking Approaches

[0004] In recent years, attempts to transform the legacy Public Switched Telephone Network (PSTN) to exploit the potential of the Internet has led to approaches that are loosely referred to as the Next Generation Network (NGN). It was believed that such approaches would lead to converged networks. Converged networks promise substantial cost savings and new service opportunities for telecommunications carriers (a.k.a. "carriers," or "network service providers"). As a means to realize new data services, carriers have deployed overlay networks, which require overlay of new infrastructure onto existing legacy voice networks. In contrast, the converged approach of the NGN seeks to eliminate the need to have separate networks for different media. It exploits the principles of "openness" and leverages the standard protocols of IP networks to carry not only data but also other media such as voice and video.

The PSTN and AIN Principles

[0005] The NGN grew out of the PSTN, thus to understand its origins one must understand present day Advanced Intelligent Network (AIN) employed by PSTN carriers to provide advanced telephony services. The AIN was proposed as the solution to the carriers' needs to produce applications rapidly and independently of switch development efforts. Prior approaches had bundled services within switches, giving rise to long development times and inflexible service deployment. Service development and deployment was intimately tied to switch evolution and switch development cycles.

[0006] AIN proposed de-coupling service development and service logic from switches by building appropriate trigger points within the switch. Upon encountering a trigger detection point while processing a call, the switch, called the Service Switching Point (SSP), would trigger and send a query to a Service Control Point (SCP). FIG. 1 illustrates the elements of AIN. The SSP performs a query directed to an SCP. The SCP executes service logic that yields a result and that result is returned to the SSP that initiated the query. The SSP then continues with call processing.

[0007] As an example, when a subscriber dials an 800 number, an SSP detects that the call requires AIN service logic processing. The SSP directs a query to an SCP which in turn executes service logic that returns a valid dialing number to the SSP. The SSP then asks the Signaling System #7 (SS#7) network to set-up a call to that telephone number. SS#7 sets up signaling and bearer paths necessary to support a call to that dialing number. The CENTRAL OFFICE SWITCH serving the called party applies a ringing tone to the called party's telephone. Once the called party answers, the call is established and both the parties can now have a telephone conversation.

[0008] FIG. 1 depicts the structure of the PSTN, including its support for AIN. The CENTRAL OFFICE SWITCH is decomposed into four distinct modules:

[0009] CALL PROCESSING

[0010] LINE

[0011] SIGNALING

[0012] TRUNK

[0013] The LINE module functions include detecting on-hook/off-hook, applying dial tone and ringing tone, collecting dialed digits, and communicating internally with the call-processing module. The CALL PROCESSING module analyzes the digits collected by the LINE module, and asks the SIGNALING module to perform appropriate actions. The SIGNALING module interfaces with the SS#7 TRANSPORT NETWORK for the purpose of setting up a bearer channel between the calling and the called CENTRAL OFFICE SWITCHES. The TRUNK module transforms analog voice to a Time Division Multiplexed (TDM) format for transmission over PSTN trunks. The TRUNK module of the CENTRAL OFFICE SWITCH serving the called party converts the TDM trunk format back to analog for transmission over the local loop.

The Next Generation Networking Model

[0014] FIG. 2 illustrates the NGN approach. The NGN exhibits several similarities to the legacy PSTN. If one were to split apart the four modules that comprise the CENTRAL OFFICE SWITCH (see FIG. 1) into separate and distinct computing elements, the following components of a NGN network result:

[0015] MEDIA GATEWAY CONTROLLER

[0016] RESIDENTIAL GATEWAY

[0017] TRUNK GATEWAY

[0018] SIGNALING GATEWAY

[0019] To compare the functions of these elements to analogous functions in the CENTRAL OFFICE SWITCH, the MEDIA GATEWAY CONTROLLER (A.K.A. "soft-switch," or "call agent") performs the functions of the CALL PROCESSING module, the RESIDENTIAL GATEWAY (A.K.A. "customer gateway") performs the functions of the LINE module and the TRUNK GATEWAY replaces the TRUNK module. Insofar as the RESIDENTIAL GATEWAY and TRUNK GATEWAY are both responsible for converting media provided in one type of network to the format required in another type of network, they are referred to generically as MEDIA GATEWAYS. With respect to support for network signaling functions, the SIGNALING GATEWAY in the NGN replaces the SIGNALING module in the CENTRAL OFFICE SWITCH. The similarities between the PSTN and NGN end here.

[0020] FIG. 2 shows a PACKET TRANSPORT NETWORK based on IP in OSI Layer 3 (the network layer) transported over ATM in OSI Layer 2 (the datalink layer). It interconnects all four NGN network elements. What were once major modules within a CENTRAL OFFICE SWITCH are now distributed network elements interconnected through a PACKET TRANSPORT NETWORK. The distributed nature of network elements in an NGN brings out one of the most striking differences between the PSTN and the NGN approaches. The theoretical advantages to be gained from this distribution include the following:

[0021] The MEDIA GATEWAY CONTROLLER may be implemented on a reliable, high-performance, fault-tolerant server that is IP-based and uses standard protocols to communicate with the gateways. Services can be implemented on separate platforms using open application programming interfaces (API), which should in theory lead to rapid development and deployment of services.

[0022] The MEDIA GATEWAYS can send media to each other over an IP-based PACKET TRANSPORT NETWORK using a protocol called Real Time Transport Protocol (RTP). The RTP protocol can be used to transmit not only voice but also data and video. The same IP transport and protocol can be used to carry multiple media types concurrently, a task that is difficult to accomplish with the circuit-switched PSTN network.

[0023] Unlike with the PSTN, where the signaling network is separate from the voice network, NGN utilizes the same PACKET TRANSPORT NETWORK to carry both signaling and media traffic.

[0024] Whereas communication between the four major modules is internal to the CENTRAL OFFICE SWITCH in the PSTN, the NGN uses a gateway control protocol for communication between the MEDIA GATEWAY CONTROLLER and the MEDIA GATEWAYS.

[0025] The most widely studied gateway control protocol is Media Gateway Control Protocol (MGCP) described by IETF RFC 3015 on Megaco Protocol Version 1.0. RFC 3015 is a common text with ITU-T Recommendation H.248, the most recent draft of which was developed as a close cooperation between the IETF Media Gateway Control Working Group (A.K.A. "MEGACO Working Group") and ITU-T Study Group 16.

[0026] The precursor to MGCP was the Simple Gateway Control Protocol (SGCP) developed by Telcordia. At about the same time Telcordia was implementing SGCP, a company called Level 3 had developed a similar protocol called IP Device Control (IPDC). Rather than have two similar protocols develop and compete over time, Telcordia and Level 3 merged them into MGCP. MGCP was tailored to address a PSTN telephone and was not designed to handle data or multimedia. ITU-T Study Group 16 extended MGCP to support ISDN and multimedia, which led to Recommendation H.248. This body of work is today referred using the moniker MEGACO/H.248; it details a NGN reference architecture that provides an operational context for the description of the MGCP itself.

[0027] FIG. 2 depicts an NGN that is architecturally compatible with MEGACO/H.248. The following workflow sequence illustrates a typical call set-up procedure for the NGN depicted in FIG. 2:

[0028] (1) A telephone goes off-hook. The RESIDENTIAL GATEWAY serving the telephone detects the off-hook event, applies dial tone, collects the dialed digits, and notifies the MEDIA GATEWAY CONTROLLER using MEGACO; The RESIDENTIAL GATEWAY also informs the MEDIA GATEWAY CONTROLLER that it is prepared to receive an RTP media stream at a certain port address, and further indicates the audio coding format it is able to support.

[0029] (2) The MEDIA GATEWAY CONTROLLER processes the digits and then must determine whether the called party telephone is connected to another RESIDENTIAL GATEWAY within the NGN or connected to a CENTRAL OFFICE SWITCH in the PSTN.

[0030] (3) Assuming the called party is connected to another RESIDENTIAL GATEWAY within the NGN, the MEDIA GATEWAY CONTROLLER queries the RESIDENTIAL GATEWAY serving the called party for an RTP port (and the audio coding format) at which it would prefer to receive an RTP stream from the calling party RESIDENTIAL GATEWAY.

[0031] (4) The called party RESIDENTIAL GATEWAY responds with the port at which it can receive an RTP audio stream from the calling party and the audio coding format it is able to support.

[0032] (5) The called party RESIDENTIAL GATEWAY applies a ringing tone to the called party's telephone.

[0033] (6) The MEDIA GATEWAY CONTROLLER informs the calling RESIDENTIAL GATEWAY of the audio coding format supported by the called RESIDENTIAL GATEWAY and the port at which it is expecting to receive an RTP stream.

[0034] (7) Following more exchanges of information, both the calling and called party RESIDENTIAL GATEWAYS know the port addresses and supported audio coding formats necessary for them to send and receive RTP streams (containing encoded audio) to/from each other.

[0035] (8) Once the called party answers the telephone, two-way communication using RTP streams is established.

Implications of NGN Deployment

[0036] There are several significant implications that result from delivering network services to subscribers through an NGN rather than the PSTN. Several of them are summarized in the points below:

[0037] Unlike the PSTN, which has a signaling network that is separate from the TDM network for establishing bearer paths, the NGN network carries both signaling and media streams over the same IP network, thereby achieving a certain measure of convergence.

[0038] Whereas the PSTN requires separate overlay networks and protocols for other media beyond voice, the NGN utilizes the same IP network and protocols for all media communications (i.e. voice, data, video).

[0039] While the PSTN carries voice media over dedicated circuit switched connections, NGN carries media streams in RTP packets that are treated in the same manner as any other IP packets, using the "best effort" paradigm the Internet employs for routing packets. This means that packets can encounter delays; they can be dropped due to congestion control mechanisms that throttle packets at the source or at the ingress to the network. Hence, the bare public Internet does not offer quality of service. Consequently, an NGN implementation requires the creation of a special-purpose IP network to support network quality of service (QoS). In contrast, the PSTN is capable of guaranteeing QoS service for point-to-point connections transporting voice or data.

[0040] The NGN interworks with the PSTN via TRUNK GATEWAYS and SIGNALING GATEWAYS. Thus, while the end-to-end connection between two NGN subscribers would occur entirely within the PACKET TRANSPORT NETWORK, the end-to-end connection between and NGN subscriber and a PSTN subscriber would occur in both the NGN and the PSTN, using a TRUNK GATEWAY and a SIGNALING GATEWAY to carry bearer channel content and network signaling information, respectively, between the two subscribers participating in the call.

[0041] Third-party applications can be offered via an open applications programming interface (API) offered by the MEDIA GATEWAY CONTROLLER. Some standards for Open APIs include PARLAY, JAIN, XML, or SOAP. It is beyond the scope of this discussion to provide definitions for these APIs or to elaborate on them beyond presenting their monikers. Let it simply be said that the thrust of these APIs was originally an effort to make AIN infrastructure in the PSTN accessible to third-party application providers so that they could offer new and innovative network services. With the advent of the NGN, it was envisioned that the same set of APIs would be suitable to provide third-party NGN applications with the ability to access similar features by interfacing with the MEDIA GATEWAY CONTROLLER.

[0042] The NGN makes it possible for a carrier to provide plain old telephone service (POTS) over a PACKET TRANSPORT NETWORK by using a MEDIA GATEWAY CONTROLLER and a RESIDENTIAL GATEWAY rather than a CENTRAL OFFICE SWITCH. As already explained, the RESIDENTIAL GATEWAY takes on the role of the LINE module of the CENTRAL OFFICE SWITCH; therefore, there are no NGN requirements to change the telephone itself.

A Victim of Failed Economics

[0043] Though the NGN is today restricted in its applicability to voice communications, it was originally the hope of both carriers and vendors that voice-over-IP (VoIP) would serve to bootstrap the NGN and spawn off a new era of converged networks that would cater to voice, video and data communications. Convergence promised to transform the PSTN into a general purpose "multi-service network" capable of simultaneously delivering voice, video and data services through a common PACKET TRANSPORT NETWORK that supports QoS. Thus far this expectation has not materialized due to the carriers' reluctance to widely deploy a network based on the NGN architecture. At the current time, many carriers perceive the NGN architecture unsuitable to meet their forward-looking objectives to decrease network operating costs while at the same time increase network service revenues. Ultimately the NGN became a victim of failed economics that resulted from its inordinate complexity and insufficient support for new services.

Complexity Confounds NGN Deployment

[0044] The inordinate complexity of the NGN is to a large extent due to overreliance on centralized control elements for network service delivery. While its many network elements may be physically distributed, the NGN architecture's logical centralization mimics the functionality of the "mainframe-oriented" PSTN. The NGN architecture has more recently been altered from its original design to model the Internet, relying upon a "horizontal integration" of specialized, cooperating network elements. Many of these network elements are not shown in FIG. 2, but are necessary for NGN implementation (e.g. feature servers, media servers, integrated access device controllers, policy servers, domain naming servers, SIP proxy servers, TRIP servers, subscriber directory servers). Very much unlike the internet, virtually all NGN network elements require some degree of centralized control by, or interaction with, the MEDIA GATEWAY CONTROLLER according to specialized protocols. All of these protocols communicate through (i.e. generate traffic on) the carrier's PACKET TRANSPORT NETWORK.

[0045] To support its centralized service delivery model, the "vertically integrated" PSTN was based on a hardware scaling model in which the majority of software processes communicated directly with each other inside purpose-built hardware computing modules. These computing modules