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physically plugged into each other to create large, distributed mainframe computers such as the CENTRAL OFFICE SWITCH. The more horizontally integrated NGN is based on a software scaling model that for all intents and purposes remains as operationally centralized as the PSTN, if not more so in some instances where control over a very large number of subscribers (potentially millions) may be aggregated into a regional office. Adherents of the NGN architecture maintain that such a high degree of centralization offers cost benefits; however, the cost benefits of centralization are to a large measure offset by fault vulnerability and the costs associated with ensuring system redundancy. Generally speaking, if something in a network does anything for thousands of subscribers at the same time, not only does the carrier need two of them, but also the ability to automatically fall over from one to the other without dramatically interrupting service delivery. Implementing this level of functionality for centralized components is obnoxious and often prohibitively expensive.

[0046] As depicted in FIG. 2, the physically distributed, highly-decomposed NGN architecture relies upon an "orchestra" of interdependent software services running on distributed network elements; these software services, each according to its unique role, communicate in one-to-one, many-to-one, or one-to-many relationships with other interdependent software services through the PACKET TRANSPORT NETWORK, each using specialized protocols.

[0047] Due to physical limitations on how many MEDIA GATEWAYS can be controlled by a single MEDIA GATEWAY CONTROLLER, the NGN must be partitioned into control zones. Local device-level signaling performed by the MEDIA GATEWAY CONTROLLER within its control zone must be somehow synchronized with end-to-end network signaling that would be necessary for a call to span more than a single zone. The result is a two-tiered signaling architecture—a concession to the inelegant NGN scaling model and its inherent requirement for network partitioning. Network signaling protocols such as Session Initiation Protocol (SIP) are used between control zones for end-to-end network signaling, whereas MEGACO is used closer to the endpoint for local MEDIA GATEWAY control.

[0048] Among other things, the two-tiered signaling model complicates the integration of APPLICATION SERVERS (and potentially PBXs) that typically require more signaling information than can be conveyed by MEGACO (e.g. calling and called party dialing numbers). As a result, network signaling using SIP must be extended directly to the APPLICATION SERVER as if it were another MEDIA GATEWAY CONTROLLER (i.e. another "control zone." Thus, for the NGN to enable network-based enhanced services such as voice mail or group conferencing, it must interface APPLICATION SERVERS using a different method than the way it interfaces telephones. From an operational perspective, the two-tiered signaling model means that the MEDIA GATEWAY CONTROLLER becomes a lynch pin, and must now actively mediate all telephone access to the APPLICATION SERVERS.

[0049] In the NGN, subscriber telephones are connected through RESIDENTIAL GATEWAYS and controlled by the MEDIA GATEWAY CONTROLLER using MEGACO. This complexity has further implications in terms of complicating overall network design, particularly with respect to

the scaling of participating network elements. Thus, as a consequence of its inordinate complexity, the NGN architecture brings with it a number of very significant implementation considerations that may be summarized as follows:

[0050] Potential poor performance resulting from the high processing overhead; network functionality is highly decomposed into distributed network elements that must communicate through the network itself using various protocols;

[0051] Numerous indeterminate scaling relationships that introduce a proportionally larger number of potential bottlenecks;

[0052] Troubleshooting procedures that must isolate and resolve problems that appear to reside in more than one place due to protocol incompatibilities;

[0053] Software integration requirements that are difficult for most carriers to support.

[0054] It is the conclusion of this analysis that the NGN architecture as represented in FIG. 2 has too many moving parts to operate efficiently. Attempts to remedy these limitations ultimately translate into implementation cost for the carrier attempting to deploy an NGN.

Insufficient Support For New Services Confound NGN Deployment

[0055] The NGN architecture suffers from insufficient support for new services. It largely replicates the telephone-oriented feature set of today's PSTN. Due to the centralized control model of the NGN, support for new network services is dependent upon the ability of the MEDIA GATEWAY CONTROLLER and APPLICATION SERVERS to provide the features that comprise a network service. Much like with the PSTN, feature delivery by a centralized controlling entity is limited by the carrier's ability (and willingness) to modify the controlling entity to provide new services. Notwithstanding the NGN vision of third-party applications and new services supported through MEDIA GATEWAY CONTROLLER APIs, as a practical matter it is a tenuous proposition to modify access to it, or add to its service load once it has been optimized to deliver a particular portfolio of services.

[0056] Beyond risks related to destabilizing the core of the network by providing API access to the MEDIA GATEWAY CONTROLLER, the generic concept of using APIs to integrate application services came into question some time after the inception of the NGN and its API-based strategy. In actual practice—"actual practice" being a function of industry consensus derived from years of internet experience—third-party applications offered through the NGN are probably better integrated using standard IP-based IETF protocols such as SIP and Hypertext Transfer Protocol. APPLICATION SERVER integration into the PACKET TRANSPORT NETWORK using internet-style protocols (based on message passing) has proven far more flexible and cost-effective than integrations based on APIs. APIs tend to be highly vendor-specific, programming language-specific, and, since they are based fundamentally on function calls rather than message sets, tend to be less tolerant of partial implementation.

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[0057] Notwithstanding the foregoing, it should be kept in mind that network signaling protocols like SIP are not compatible with the device-oriented MEGACO protocol used to control telephones connected to RESIDENTIAL GATEWAYS. Thus, as pointed out earlier in the discussion, the two-tiered signaling model of the NGN puts the MEDIA GATEWAY CONTROLLER into a mediation role, performing an imperfect translation between its use of MEGACO to control service delivery to telephones and its use of SIP as the means to access application services.

[0058] Interactive calling services were originally envisioned that would provide the NGN subscriber with the ability to select or customize call processing logic, perhaps even to enable interoperability between network features and application programs running on the subscriber's personal computer (e.g. active browser sessions, instant messaging clients) or to access subscriber-specific data objects (e.g. contact lists, call logs, content subscriptions). Implementation of these types of interactive calling services using only AIN-style APIs was eventually perceived as largely impractical in the NGN because the MEDIA GATEWAY CONTROLLER (supporting the APIs) would be required to access, manage, and execute unique, complex service logic for very large number of subscribers at the same time. The following points illustrate other significant limitations of the NGN with respect to supporting new services:

[0059] In the NGN, the MEDIA GATEWAY CONTROLLER delivers telephone features by remotely controlling the RESIDENTIAL GATEWAY. It can only deliver features through a RESIDENTIAL GATEWAY whose feature set it fully understands according to the MEGACO standard. This factor imposes substantial constraints on the variety of network services the NGN can deliver because it is impractical or infeasible to control an endpoint feature set that extends beyond that anticipated by MEGACO.

[0060] Calling services that perform call control operations require a full knowledge of subscriber Class of Service parameters and service delivery preferences. This information governs not only the subscriber's ability to invoke the calling service in the first place, but the unique behavior of the service when invoked by that particular subscriber. Most of the information that interactive calling services (e.g. call log functions, programmable call-blocking and call-forwarding) require is buried somewhere deep inside the NGN infrastructure in much the same way that it was buried inside the CENTRAL OFFICE SWITCH in the PSTN. This factor imposes substantial constraints on the variety of network services the NGN can deliver because call log entries and related subscriber-specific network usage data are largely unavailable for real-time access by third-party applications.

[0061] RESIDENTIAL GATEWAYS are unintelligent in the sense that they require the MEDIA GATEWAY CONTROLLER to mediate all network signaling functions on their behalf. They cannot determine the broader network signaling context of the calling operations in which they participate. They are incapable of independently executing service

logic that involves network signaling operations (e.g. call redirection, multipoint call control, call supervision, multiple line appearances, etc.) without centralized participation by the MEDIA GATEWAY CONTROLLER. These factors impose substantial constraints on the variety of network services the NGN can deliver because each new service must be tightly integrated with the MEDIA GATEWAY CONTROLLER in order to perform call control operations.

[0062] To work around these constraints, recent approaches to offering new services in the NGN have put an application between the RESIDENTIAL GATEWAY and the MEDIA GATEWAY CONTROLLER. The application is responsible for controlling the subscriber's telephones, giving them access to various new features. These approaches support: (a) a variety of telephone types not supported by standard MEGACO; (b) better access to call log records and related subscriber-specific network usage data; and (c) the ability to execute user-configurable service logic not supported by the MEDIA GATEWAY CONTROLLER.

[0063] As an example of this approach, companies such as Cisco, Broadsoft, LongBoard, and Syntario have built application systems that provide optimized combinations of business telephone services that include FEEX and Centrex features. While some of these solutions are designed for enterprise deployment, those intended for carrier deployment are often referred to using the moniker "IP Centrex." IP Centrex solutions provide calling services and telephone features using various brands of office telephones and web browser-based graphical user interfaces. Generally, IP Centrex solutions equate to a network-based software FEEX application that replaces much of the functionality of the MEDIA GATEWAY CONTROLLER.

[0064] IP Centrex solutions are often referred to in the industry as "point solutions." Point solutions enable the carrier to provide a very particular set of new services for isolated populations of subscribers. They are a work-around borne out of necessity and introduce additional "non-standard" intermediary network elements into the NGN. Adding new network elements of this type brings with it significant scaling implications associated with carrier deployment of a service that cannot scale as the network itself scales. Point solutions are operationally infeasible for carriers serving tens of millions of subscribers because the feature set of the point solution cannot be managed as a standard network feature set that may be enabled or disabled for any subscriber at will. If such a service became popular, the carrier would have to replicate many instances of the system—potentially thousands of them—each to serve a certain critical mass of subscribers, and then to manage these systems as independent islands of service delivery capability.

[0065] As summarized below, point solutions bring with them their own unique set of carrier deployment challenges and at the same time do not resolve the general limitations of the NGN with respect to supporting new services:

[0066] Point solutions do not in a general sense enable the NGN to control a telephone feature set (or other endpoint device feature set) that extends beyond that anticipated by MEGACO, but instead supports selected vendor telephones in a way that suits their own specific purposes.

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[0067] Point solutions do not in a general sense make call log records and related subscriber-specific network usage data available for real-time access by a third-party applications, but instead simply store it internally for their own use.

[0068] Point solutions do not in a general sense make it possible for third-party applications to perform call control operations, but instead implement call control operations for their own specific purposes.

NGN Support For Multi-Service Delivery

[0069] The NGN architecture leaves to future consideration features sets that extend beyond traditional PSTN voice services. It assumes central office (or equivalent) deployment for most network elements and that the RESIDENTIAL GATEWAY is providing telephone services over a general-purpose PACKET TRANSPORT NETWORK that supports QoS. Video and data services are not addressed directly by the NGN, and it is assumed that other network elements and related infrastructure components will provide these services independently.

[0070] The above assumptions do not anticipate that the subscriber purchasing voice services is also likely to purchase data and video services from the same carrier. When the carrier's primary connection to the subscriber premise is through a broadband access network, it quickly become impractical to install a separate physical connection or independent solution for each type of media service offered to that subscriber. Much of the motivation behind the transition to a converged network is based on the notion that multiple services—voice, video, and data services—can be offered to a network subscriber through a single IP data path to the premise. The converged vision extends to enabling carriers to combine several media types into a comprehensive network services offering.

[0071] This type of multi-service delivery requires QoS arbitration at the subscriber premise so as to ensure QoS for all voice, video, and data terminal devices (i.e. telephones, televisions, PCs) installed there; all of these terminal devices may be operating at the same time sharing the same IP data path. Many potential new services anticipate providing value to subscribers because of their ability to support multiple media types at the same time, potentially integrating two services that support different media types in a way that makes each more useful. In addition, voice, video and data terminal devices installed at the subscriber premise often support different control interfaces that must be normalized to network signaling and device control conventions that would enable them to interact with network-based APPLICATION SERVERS in a consistent fashion.

[0072] Equipment vendors have responded to requirements to enable NGN multi-service delivery through a single IP data path to the subscriber premise by creating an integrated access device (IAD). The IAD began life as specialized version of a RESIDENTIAL GATEWAY, designed as a means to enable subscribers to connect voice and data terminals at the premise in such fashion as they may share a common IP data path to the carrier's PACKET TRANSPORT NETWORK. The IAD marketplace today offers the carriers a bewildering assortment of devices, targeting optimal combinations of cost effectiveness and/or feature richness.

[0073] Some IADs support voice-over-IP and QoS arbitration features whereas others attempt to obviate total reliance on remote IAD control by a MEDIA GATEWAY CONTROLLER (using MEGACO) by implementing selected POTS telephone features and SIP network signaling within the IAD. Some IADs used by the cable industry do not support VoIP in the NGN sense of it, but instead provide for "voice-over-broadband." The term voice-over-broadband refers to a family of proprietary access network designs, the most common of which is that used by cable companies that transport voice, as well as data and video, on distinct broadband channels created through frequency division multiplexing (FDM). In this type of voice-over-broadband network, voice and data flows are split at the central office (or central office equivalent), with the voice path connecting to a CENTRAL OFFICE SWITCH (usually through a GR 303 packet interface). IADs of this type are excepted from this discussion because they do not support the converged "end-to-end IP" vision of the NGN and are fundamentally incompatible with it.

[0074] NGN voice services offered through an IAD using VoIP are virtually identical to voice services offered directly through a POTS line connected to a CENTRAL OFFICE SWITCH. Typically, the IAD is used to connect telephones and computers in a broadband data service provided to the premise. Through the gateway facilities of the IAD, voice and data are transported as distinct packet flows over a common IP data path that is contiguous (from an IP connectivity standpoint) with the PACKET TRANSPORT NETWORK. In the NGN, the feature set of the CENTRAL OFFICE SWITCH is emulated by the MEDIA GATEWAY CONTROLLER in concert with a number of other network elements such as a "feature server." Conceptually, in the NGN the IAD functions exactly as any other RESIDENTIAL GATEWAY.

[0075] Unable to deliver traditional PSTN network services independently, and devoid of the ability to enable compelling new service capabilities, the value proposition of the IAD lies in its ability to enable the subscriber to use one physical line (e.g. DSL line, cable, T1) for both voice and data at the same time. In summary, the cost of the IAD must be compared to the cost of simply installing separate voice and data lines to the premise.

[0076] After substantial field experience, technical staff at two major United States Local Exchange Carriers recently concluded that the cost for them to deploy network services using an IAD is greater than or equal to the cost to deploy separate voice and data lines to the premise, except in rare cases where it would be exceptionally expensive to bring to an additional line. Despite wide availability several for years, the limited deployment of IADs further suggests that the NGN has been a victim of failed economics. From a pure technical perspective, an IAD may be an appropriate "edge device" form-factor to address MEGACO requirements for multi-service delivery to the subscriber premise. This observation does not remedy the underlying problem that its cost to deploy is perceived as more than can be justified by the modest functionality it enables.

SUMMARY

An Edge Switched Network Architecture

[0077] An Edge Switched Network (ESN) architecture is introduced as an innovation whose implementation is depen-

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dent upon the Distributed Edge Switch (the "invention" that is the subject of this disclosure). The general operating principles of the ESN are described below as a prelude to a detailed description of the Distributed Edge Switch (DES) found in the OVERVIEW section. It will be shown that the ESN resolves many of the limitations inherent to the NGN.

[0078] FIG. 3 depicts an ESN architecture principally comprised of "connectivity elements." A connectivity element is a particular type of network element that is capable of participating in call sessions using SIP network signaling and RTP bearer transmission. Communities of connectivity elements communicate in a peer-to-peer fashion without necessarily requiring assistance from the network beyond IP connectivity. The three connectivity element types defined for the ESN are as follows:

[0079] EDGE SWITCH

[0080] APPLICATION SERVER

[0081] PSTN GATEWAY

[0082] All three connectivity elements share a similar network interface design that combines support for SIP network signaling, RTP bearer transport, media encoding/decoding, and event-driven call processing into a single intelligent endpoint device. From a conceptual standpoint, each connectivity element collapses functionality from each major NGN network element into a self-contained whole capable of "intelligent participation" in call sessions. Intelligent participation refers to the ability of a connectivity element to operate both as SIP network signaling endpoint and as a call control agent capable complex call control operations. Complex call control operations might involve supervising call sessions that contain multiple call legs extending to other connectivity elements. Connectivity elements may leverage network-based SIP proxy servers to support these and other complex operations.

Role of the Edge Switch in the ESN

[0083] The EDGE SWITCH is an ESN connectivity element whose principal function is to support the delivery of voice, video (multimedia) and data services—multi-service delivery—to the subscriber premise through a shared IP data path. It aggregates several functions together into a single, cost-effective device that is deployed by the carrier as a premise-based network element.

[0084] FIG. 3 shows that the EDGE SWITCH functions as a broadband access network termination device (e.g. DSL modem, cable modem, T1 terminator, passive optical terminator) at the subscriber premise, providing an IP data path from the premise to the PACKET TRANSPORT NETWORK. It also provides a means by which voice, video and data terminals at the subscriber premise may connect to other network endpoints in the PACKET TRANSPORT NETWORK, each creating connections through a shared, routed IP data interface.

[0085] Ultimately, all subscriber terminals plugged into the EDGE SWITCH communicate with the PACKET TRANSPORT NETWORK through QoS routing capabilities built into the EDGE SWITCH. EDGE SWITCH routing capabilities enable QoS arbitration at the exact point where subscriber terminals interface the broadband access network. Video streaming services deployed within the network

are made accessible to SIP media streaming devices connected to the EDGE SWITCH (such as SIP-enabled set-top boxes). Data transmission capacity not used for voice telephone communications or media streaming is made accessible to data terminals for data communications. The EDGE SWITCH operates as a MEDIA GATEWAY to the extent that it is able to present POTS or other types of non-SIP telephones (connected through its LINE interface) to the network as SIP network signaling endpoints. The EDGE SWITCH provides necessary terminal adaptation as necessary for the conversion of device signaling and bearer channel content at the LINE interface to/from SIP network signaling and RTP voice transmission conventions required by the ESN.

[0086] The EDGE SWITCH executes locally stored call processing applications in response to detecting network trigger events. In this way, voice telephone features and related calling services are provided by the EDGE SWITCH to the subscriber through legacy POTS and/or IP telephones, without the participation of centralized network control elements.

[0087] In order to perform in the capacities described above, the EDGE SWITCH must operate as a general computing device able to execute complex software programs and store relatively large amounts of information. More specifically, the EDGE SWITCH contains the following:

[0088] Sufficient computing capacity, memory, and operating system functionality necessary to support application-level program development and application program execution; particularly the execution of call processing applications;

[0089] Sufficient storage capacity to hold an operating event history of a year or more; operating events include configuration changes and all potentially billable subscriber access to calling services (e.g. call log records);

[0090] Sufficient storage capacity to hold all call processing application executable code needed to support network service delivery according to the subscriber's Class of Service;

[0091] Sufficient storage capacity to hold local call routes and network addressing information needed to support network service delivery (via call processing applications) for all subscribers served by the EDGE SWITCH;

[0092] Sufficient storage capacity to hold subscriber Class of Service parameters and service delivery preferences needed to govern the subscriber's ability to invoke a particular calling service and the unique behavior of the service when actually invoked.

[0093] System software to support a SIP network signaling protocol stack that can be programmed to selectively expose trigger points in a call that automatically invoke service logic (i.e. call processing applications).

[0094] System software to support centralized service provisioning, device management, and software upgrades by a remote system management platform

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[0095] System software to support the full complement of QoS arbitration, including traffic classification, packet labeling, packet scheduling, and admission control based on subscriber Class of Service.

[0096] System software to support real-time remote monitoring of network service delivery, with active reporting of status to a remote system management platform.

[0097] System software required to meter network service delivery by generating call log records and to store them in a database internal to the EDGE SWITCH.

[0098] System software required to normalize vendor-specific terminal device interfaces to comply with network signaling and device control conventions that would enable them to interact with network-based APPLICATION SERVERS in a consistent fashion.

[0099] Secure data exchange interfaces that make EDGE SWITCH features and all information stored within its internal databases accessible to remote database clients, network management systems, and third-party applications.

Role of the Application Server in the ESN

[0100] The APPLICATION SERVER is an ESN connectivity element whose principal function is to support the delivery of network services to other ESN connectivity elements. As is common to all ESN connectivity elements, the APPLICATION SERVER is capable of intelligent participation in call sessions. It can execute internally stored call processing applications (service logic) in response to network signaling events and related trigger points in a call. An example of signaling events that would trigger service logic execution include an attempt by a SIP signaling endpoint to connect to the APPLICATION SERVER or disconnect from it once connected. Trigger points in a call might include events detected while the SIP call session is in progress, such as mid-session control messages or certain call control operations.

[0101] In most scenarios, network services or features supported by an APPLICATION SERVER are rendered directly to SIP network signaling endpoints that connect to it. For reasons of security and protocol compatibility, the APPLICATION SERVER may implement secure connection policies that prohibit access to SIP network signaling endpoints that are not directly managed or mediated by another ESN connectivity element. For example, a PC-based SIP client attempting to connect to the APPLICATION SERVER through the public internet may be prohibited from doing so; however, a PC-based SIP client attempting to connect to the APPLICATION SERVER through an EDGE SWITCH will have its SIP signaling mediated by that EDGE SWITCH—perhaps encrypted according to an internal carrier network standard—and as a result may be allowed to connect to the APPLICATION SERVER in this way.

[0102] Upon detecting a SIP call session initiation, the APPLICATION SERVER examines SIP signaling information and compares it with what it knows internally about the calling party so that it may automatically determine the feature, function, or service that it should render to the

calling party. For example, if the calling party is a SIP network signaling endpoint (SIP User Agent) used by an EDGE SWITCH to represent a POTS telephone at the subscriber premise, the APPLICATION SERVER will receive the dialing number of the calling party (i.e. the dialing number assigned to the POTS telephone originating the call). It may then use this dialing number to access an internal database for the purpose of retrieving the Class of Service parameters associated with this dialing number. Class of Service parameters will inform the APPLICATION SERVER as to whether or not it should render its service to the calling party.

[0103] Aside from the number of simultaneous SIP call sessions it can potentially support—a function of its hardware form-factor—there is a fundamental difference between the APPLICATION SERVER and the EDGE SWITCH: whereas the APPLICATION SERVER renders network services and features to a calling party, the EDGE SWITCH renders network services and features to terminal devices plugged into it at the subscriber premise.

[0104] In rendering network services and features to a calling party, the APPLICATION SERVER exploits the capabilities of various system resources. Call processing applications executing on the APPLICATION SERVER may perform database queries, media store-and-forward operations, support group conferencing, convert text to speech, recognize voice commands, or any one of a number of operations that might be beyond the scope of what an EDGE SWITCH could perform without assistance from the network. By simply connecting to an APPLICATION SERVER, an EDGE SWITCH or PSTN GATEWAY may request and receive the intelligent participation of the APPLICATION SERVER when they require such assistance.

Role of the PSTN Gateway in the ESN

[0105] The PSTN GATEWAY is an ESN connectivity element whose principal function is to (a) make it possible for the EDGE SWITCH to connect to PSTN endpoints using SIP network signaling and (b) to make it possible for PSTN endpoints to connect to the EDGE SWITCH using PSTN network signaling. The PSTN GATEWAY combines the functions of the NGN architecture's SIGNALING GATEWAY, TRUNK GATEWAY, and MEDIA GATEWAY CONTROLLER so as to enable SIP call sessions connecting to it to be bridged to PSTN endpoints. It provides necessary signaling gateway functions as required to interface the PSTN using SS7 protocols. It also provides necessary media gateway functions to convert bearer channel encoding formats at the TRUNK interface to/from SIP and RTP voice transmission conventions required by the ESN.

[0106] A connection attempt that originates in the ESN and that is intended to ultimately connect to a PSTN endpoint, will be directed to a SIP network signaling endpoint on a PSTN GATEWAY. The PSTN GATEWAY will initiate essentially the same workflow sequence used by the APPLICATION SERVER to execute internally stored call processing applications. Consistent with its specialized role in the ESN, the PSTN GATEWAY will execute a call processing application that will connect the incoming SIP call session through to the specified PSTN endpoint. Thus, an incoming SIP call from the ESN to the PSTN GATEWAY

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will initiate a corresponding PSTN call set-up to a PSTN endpoint through the TRUNK interface. In the reverse direction, an incoming PSTN call through the TRUNK interface will result in a SIP call set-up to a SIP network signaling endpoint in the PACKET TRANSPORT NETWORK.

Architectural Comparison of ESN to NGN

[0107] The ESN is substantively different from the NGN in a number of significant ways, and as a result of these differences, the ESN remedies certain architectural limitations inherent to the NGN as set forth in the foregoing sections. By showing how specific limitations of the NGN are resolved by the ESN, the summary below affords an opportunity to highlight important capabilities inherent to the ESN architecture within a relevant context:

[0108] (1) The potential poor performance of the NGN resulting from high processing overhead for distributed elements communicating through the network (and attendant scaling problems related thereto) is resolved by the following:

[0109] Eliminating the MEDIA GATEWAY CONTROLLER function entirely, and instead distributing call processing capability throughout the network by embedding it in intelligent endpoint devices;

[0110] Feature-oriented network service delivery to subscribers through terminals at the premise is performed by dedicated computing resources physically located on the subscriber premise (i.e. by the EDGE SWITCH);

[0111] To the extent that the above method of feature delivery does not require assistance from the network for most call processing functions, feature responsiveness is perceived by ESN subscribers to be essentially instantaneous, regardless of the number of simultaneous ESN network users;

[0112] As a consequence of eliminating the MEDIA GATEWAY CONTROLLER function entirely, so too is the gateway control layer eliminated, effectively flattening the two-tiered NGN network signaling model into a normalized SIP network signaling model. According to the normalized SIP network signaling model, voice and multimedia connections are established peer-to-peer using the same method;

[0113] As a result of flattening the two-tiered NGN network signaling model into a normalized SIP network signaling model, overall ESN system performance with respect to APPLICATION SERVER access by EDGE SWITCHES and PSTN GATEWAYS is dramatically enhanced. The delivery of network-based features provided by APPLICATION SERVERS in the ESN is perceived by subscribers to be essentially instantaneous and relatively unaffected by the number of simultaneous ESN network users.

[0114] (2) The NGN's large number of potential bottlenecks that are introduced as a result of its numerous indeterminate scaling relationships are resolved by the following:

[0115] Reducing the number of network elements that are needed to participate in network service delivery;

[0116] Embedding feature delivery and service metering functions into the network access device (EDGE SWITCH or PSTN GATEWAY) so as to eliminate requirements for the centralized network elements to retain information about the state of any given call.

[0117] (3) Troubleshooting procedures for the NGN must isolate and resolve problems that appear to reside in more than one place because of protocol incompatibilities. This issue is resolved in the ESN by the following:

[0118] Reducing the total number of protocols;

[0119] Reducing the total number of network elements;

[0120] Managing all connectivity elements as populations of like elements, each of which supports more or less identical provisioning, device management, diagnostic, and event reporting mechanisms, and each using the same interface protocols to support similar tasks.

[0121] (4) Software integration requirements for the NGN are difficult for most carriers to implement and support. This issue is resolved in the ESN by the following:

[0122] Supporting a hardware scaling model in which ESN service delivery capability is built up in a predictable, linear fashion by replicating connectivity elements;

[0123] Embedding most subscriber-oriented features into a very low-cost device (EDGE SWITCH) that is physically replaced if an error condition is detected rather than repaired; the replacement unit is then automatically detected and re-synchronized with a system management platform so that identical network service capabilities are restored to the subscriber;

[0124] Requiring relatively few centralized software processes to support feature-oriented network service delivery, as compared to the NGN;

[0125] Utilizing SIP-based access to service logic running within APPLICATION SERVERS for advanced feature support—a method that sharply contrasts with NGN support for API access to call processing capabilities within the MEDIA GATEWAY CONTROLLER.

[0126] (5) The economic model for the NGN that has not proved compelling to carriers largely due to high implementation costs resulting from its inordinate complexity. The relative simplicity of the ESN translates into a lower relative cost for greater network service delivery capability, thereby increasing the likelihood that its economic model would be compelling enough to motivate carrier implementation.

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Some of the principal reasons for its simplicity relative to the NGN include the following:

- [0127] The ESN is capable of delivering traditional PSTN network services and new multi-service capabilities through a common means with little or no reliance on feature-controlling infrastructure in the central office;
- [0128] The ESN employs a hardware scaling model that uses primarily mass produced, low-cost EDGE SWITCHES for most of its subscriber-oriented service delivery;
- [0129] The ESN requires dramatically less effort to test compared to the NGN, since validating the feature set of a single EDGE SWITCH for a certain number of concurrent sessions confers validation of the ability to support any multiple of that certain number of concurrent sessions by deploying a proportionate multiple of additional EDGE SWITCHES;
- [0130] The ESN enjoys very low implementation costs due to the fact that its network integration is based on relatively few protocols other than SIP. The MEGACO protocol stack is eliminated from the model, along with all attendant requirements for licensing and interoperability testing between MEGACO-compliant network elements.
- [0131] As a consequence of these factors, overall system cost for the ESN on a per-user basis has been calculated to be less expensive than PSTN technology to provide an equivalent feature. Overall system cost for the ESN has been estimated to be less expensive than the NGN to provide an equivalent feature.
- [0132] In consideration of the above cost estimates, it should be noted that indeterminate scaling relationships in the NGN, and the lack of deployed NGN networks that could be used for direct comparison, are factors that together confound attempts to quantify the true implementation cost of an actual NGN deployment. A theoretical calculation of cost-per-subscriber (i.e. an estimate) in the NGN might not necessarily reflect actual feature delivery capacity because of unanticipated effects that are likely to result from its highly decomposed architecture.
- Support for New Services in the ESN
- [0133] Support for new services by the ESN is made possible because of several capabilities that are inherent to its architecture. Some of these capabilities are described as follows:
- [0134] The ESN supports voice, video and data-oriented network services through a common (i.e. shared) IP data path, providing QoS arbitration at the premise as is required to support multi-service delivery; thus, new services can be offered for each type of media, or new services can combine features that involve more than one type of media into a single multimedia service. As an example, a feature could be created to lower the volume of the television if someone answered the telephone;
- [0135] Feature delivery by the EDGE SWITCH is remotely programmable by the carrier; software loads can be uploaded into the EDGE SWITCH to introduce new features over time without network infrastructure changes;
- [0136] The ESN subscriber may interact with the EDGE SWITCH to select features and programs them to behave according to subscriber-specific parameters, potentially to interoperate with a variety of third-party applications, application programs running on the subscriber's PC, or to securely access data objects stored in network servers or on the subscriber's PC. As an example, an application could use instant messaging to inform the end user as to the identity of a calling party.
- [0137] Most ESN network intelligence is located within the EDGE SWITCH itself. A large part of this "network intelligence" includes the EDGE SWITCH'S ability to internally store call log records and other subscriber-specific information related to network service delivery. This stored information in effect comprises a distributed database of virtually unlimited scalability. New service opportunities are made possible by virtue of the fact that this information may be securely accessed by an application and subsequently presented to an end user within the context of interactive calling services. As an example, network-based web applications may be created to provide end users access to multi-year call histories managed through a web browser-based graphical user interface.
- [0138] Because of its SIP-based network signaling model, the EDGE SWITCH can perform complex call control operations that involve SIP network signaling endpoints located virtually anywhere in the network. This support for complex call control operations by the EDGE SWITCH in effect enables it to function as a distributed call control resource of virtually unlimited scalability. New service opportunities are made possible by virtue of the fact that this capability can be securely accessed by an application and subsequently presented to an end user within the context of interactive calling services. As an example, network-based web applications may be created to provide end users the ability to access EDGE SWITCH calling features through a web browser-based graphical user interface.
- [0139] EDGE SWITCH call control operations can be used to transparently access network-based features provided by APPLICATION SERVERS. As a result, combinations of call control features internal to the EDGE SWITCH and network-based features that are external to the EDGE SWITCH can be dynamically configured and presented together to end users as a unified service or capability—that is, presented in such a way that the source of the feature (internal to the EDGE SWITCH or network-based) is entirely transparent to the end users. Thus, beyond its ability to support programmable internal feature sets via software upgrades and configurable call processing applications, the EDGE SWITCH feature set may be further extended through transparent integration with network-based features. As an example, an EDGE SWITCH feature may be created to over-

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rite basic dial-tone service; when an EDGE SWITCH detects that a telephone plugged into it went off-hook, the override feature would forgo the basic dial-tone service and instead transparently connect to a network-based voice-activated dialing application.

[0140] In general, in one aspect, the invention features a network device including a plurality of communication interfaces, among which there is a telephone line interface, a computer data interface, and a broadband network interface. The network device also includes a processor; a machine-readable storage medium which during use stores a call processing application and service profiles, and which stores executable instructions to mediate communications between the plurality of communication interfaces, the instructions causing the network device to detect network signaling events or trigger points in a telephone call and invoke the call processing application in response to the detected network signaling events or trigger points, the call processing application operating according to parameters defined in the service profiles.

[0141] Preferred embodiments include one or more of the following features. The plurality of communication interfaces further includes a video streaming device interface. The broadband network interface terminates a broadband network link that joins a customer premises to a packet carrier network. The instructions further cause the network device to route IP data between the computer data interface and the broadband network interface. The network device is contained in a single physical enclosure. The instructions further cause the network device to provide a first SIP proxy agent to represent a telephone that uses the telephone line interface, and provide a second SIP proxy agent to represent a computer that uses the computer data interface. The storage medium stores call routing tables, and the instructions further cause the network device to perform call routing for telephone calls that use the telephone line interface. The storage medium also stores call routing tables, and the instructions cause the network device to perform call routing for telephone calls according to the call routing tables, the telephone calls using the telephone line interface.

[0142] In general, in another aspect, the invention features a network device including a plurality of communication interfaces among which there is a telephone line interface, a computer data interface, and a broadband network interface. The network device also includes a processor; a machine-readable storage medium which during use stores call routing tables, and which stores executable instructions to mediate communications between the plurality of interfaces, the instructions causing the network device to perform call routing according to the call routing tables, the telephone calls using the telephone line interface.

[0143] Preferred embodiments include one or more of the following features. The call routing includes peer-to-peer call signaling between customer premises over a shared IP network. The call signaling is performed without requiring stateful elements of the shared IP network above the IP infrastructure. The broadband network interface terminates a link that joins the network device to the shared IP network. The call routing includes call signaling to a PSTN endpoint via a PSTN gateway that is reachable over the broadband network interface. The instructions further cause the net-

work device to route IP data between the computer data interface and the broadband network interface. And the plurality of communication interfaces further includes a video streaming device interface.

[0144] In general, in still another aspect, the invention features a network device including a plurality of communication interfaces, among which there is a telephone line interface, a computer data interface, and a broadband network interface. The network device also includes a processor; and a machine-readable storage medium which stores executable instructions to mediate communications between the plurality of interfaces, the instructions causing the network device to log a telephone event record in a telephone event repository, the event record describing a telephone call communication mediated by the network device.

[0145] Preferred embodiments include one or more of the following features. The telephone event repository can be included in the network device or be remote relative to the network device. The network device is housed in a single physical enclosure.

[0146] In general, in still yet another aspect, the invention features a network device includes a broadband network interface; a plurality of interfaces, among which there is a telephone line interface and a computer data interface; a processor; and a machine-readable storage medium that stores processor-executable instructions to provide proxy agents. The instructions cause the network device to provide a telephone SIP proxy agent to represent a non-SIP telephone that uses the telephone line interface; provide a distinct SIP proxy agent for each additional device that uses an interface in the plurality of interfaces; and cause the network device to implement a proxy server that mediates all SIP communications over the broadband network interface involving the non-SIP telephone and the each additional device.

[0147] In general, in another aspect, the invention features a method for establishing a voice-over-packet network architecture. The method includes locating a system management platform in a shared packet network, the system management platform collecting call log data from a plurality of network devices; and distributing the plurality of network devices that each include a telephone line interface, a computer data interface, a broadband network interface (terminating a link from the shared packet network, a processor, and a machine-readable storage medium storing processor-executable instructions to control telephone calls, the instructions causing each network device to route telephone calls in a peer-to-peer fashion over the shared packet network and to send call log data to the system management platform.

[0148] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

Conventions

[0149] Figures utilize a dotted-decimal number scheme to identify system elements using a bracket notation shown as

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"[number]." The decimal is used to denote a sub-element dependency. Programmatic relationships and call signaling pathways are numbered using a curly brace notation shown as "{number}" where the number is a tag used to identify these relationships and pathways in the discussions and do not imply order of operations. With respect to the relationship between network elements and network connectivity clouds shown in the figures, solid connector lines denote physical network interfaces whereas dotted lines denote message-passing protocol relationships in which protocol data units are exchanged through an IP data path. Many discussions will apply terminology based on the seven layer Open System Interconnection (OSI) Reference Model.

[0150] A DEFINITIONS section provides detailed descriptions of selected terms and system elements as they pertain to the invention. The DEFINITIONS section follows the OVERVIEW section. System elements that are depicted in figures will show a number identifier in brackets so that they may cross-referenced.

Table of Figures

- [0151] FIG. 1 shows the structure of PSTN and AIN with Signaling, Transport, and Service Control.
- [0152] FIG. 2 shows a Next Generation Network Architecture.
- [0153] FIG. 3 shows An Edge Switched Network Architecture.
- [0154] FIG. 4 shows A Distributed Edge Switch.
- [0155] FIG. 5 shows the Edge Switch Hardware Architecture.
- [0156] FIG. 6 shows the Edge Switch Software Architecture.
- [0157] FIG. 7 shows the Edge Switch Call Model.
- [0158] FIG. 8 shows the Distributed Edge Switch Carrier Network Reference Architecture.
- [0159] FIG. 9 shows the Distributed Edge Switch System Management Workflow.
- [0160] FIG. 10 shows the Distributed Edge Switch Call Signaling Workflow.
- [0161] FIG. 11 shows the Distributed Edge Switch as Distributed SIP Proxy Server.
- [0162] FIG. 12 shows the Distributed Edge Switch Network Service Delivery Workflow.
- [0163] FIG. 13 shows an Edge Switch For Residential Subscriber Deployment Using VDSL Broadband Access Network.
- [0164] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

Overview

[0165] The DES described below is now whereas the PSTN GATEWAY and APPLICATION SERVER elements of the ESN are assumed to represent existing specific categories of network elements originally designed for inte-

gration into the NGN. Since they present themselves to the network as SIP network signaling endpoints, they are also suitable for deployment within the ESN.

[0166] In the ESN architecture, the EDGE SWITCH serves as the means to deliver network services to subscribers. The DES is an implementation of the EDGE SWITCH described for the ESN, and thus should be viewed as its functional equivalent. While the BACKGROUND section focused on the role of a generic EDGE SWITCH in the ESN, this OVERVIEW section, in conjunction with the DEFINITIONS section and FIGS. 4-11, provides sufficient technical information necessary to implement an actual EDGE SWITCH in the form of a DES. Most detailed technical descriptions of hardware and software subcomponents, and their detailed functional contributions, are contained with the DEFINITIONS section. This OVERVIEW section will focus on articulating their respective roles as DES system elements with the architectural context of the ESN.

[0167] FIG. 13 depicts an embodiment of an actual EDGE SWITCH design that is suitable for residential subscriber deployment using a Digital Subscriber Line (DSL) connection to a broadband broadband access network.

[0168] FIG. 4 depicts the two basic elements that comprise the DES: the EDGE SWITCH [1] and the SYSTEM MANAGEMENT PLATFORM [2]. As shown, the SYSTEM MANAGEMENT PLATFORM [2] resides within the IP CARRIER NETWORK [6] whereas the EDGE SWITCHES [1] are deployed at the subscriber (customer) premise. A description of these individual elements may be found in the DEFINITIONS section.

[0169] FIG. 4 shows network elements of the DES apart from the full complement of those shown for the ESN architecture; as a result, FIG. 4 serves to aid in understanding the DES itself.

Form-Factor Considerations

[0170] The EDGE SWITCH [1] can be constructed to support any number of form-factors, depending upon the transmission capacity of the BROADBAND ACCESS NETWORK [6.1] and the number of TELEPHONE STATIONS [3] and SET-TOP BOXES [4] the designer believes is appropriate for a single instance of an EDGE SWITCH [1]. FIG. 4 depicts three distinct form-factors, with EDGE SWITCHES [1] labeled A, B, and C supporting 1, 4, and 8 TELEPHONE STATIONS [3] respectively.

[0171] The choice of form-factor will affect the ratio of TELEPHONE STATIONS [3] to COMPUTER WORKSTATIONS [5]. Regardless of the number of TELEPHONE STATIONS [3] supported by a given EDGE SWITCH [1] form-factor, one instance of an EDGE SWITCH [1] will support only one COMPUTER DATA INTERFACE [4]. This circumstance results because the basic design of the EDGE SWITCH [1] is to manage all of the transmission capacity for a single physical connection to the BROADBAND ACCESS NETWORK [6.1], and to manage it as a shared IP data path for use by all terminal devices connected to it. Any transmission capacity that is not used for voice and video call sessions is made available for common data transport through the COMPUTER DATA INTERFACE [4]. As shown for the EDGE SWITCHES [1] labeled B and C, an ETHERNET HUB [9] may be plugged in place of a COMPUTER WORKSTATION [5] for the purpose of distributing data service to several COMPUTER WORKSTATIONS [5].

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**IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
TEXARKANA DIVISION**

ESN, LLC,)	
)	
Plaintiff,)	
)	
v.)	Civil Action No. 5:07-cv-156-DF-CMC
)	
CISCO SYSTEMS, INC., and)	
CISCO-LINKSYS, LLC,)	
)	JURY DEMANDED
Defendants.)	

EXHIBIT A

Part 2

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Data Service Aggregation

[0172] Any number of EDGE SWITCHES [1] may be deployed at a single subscriber premise. If the subscriber has more TELEPHONE STATIONS [3] or SET-TOP BOXES [4] than can be supported by a single EDGE SWITCH [1], another EDGE SWITCH [1] is connected to the BROADBAND ACCESS NETWORK [6.1] to enable more TELEPHONE STATIONS [3] and/or SET-TOP BOXES [4] to be plugged in. Deploying more than one EDGE SWITCH [1] at the same premise may require that the COMPUTER DATA INTERFACES [1.4] are aggregated together into a single data service—the subscriber is likely to want all COMPUTER WORKSTATIONS [5] at the premise to be interconnected through a common local area network (LAN) with a single uplink to the public network (i.e. Internet).

[0173] For purposes of data service redundancy and increased bandwidth, many businesses aggregate a number of BROADBAND ACCESS NETWORK [6.1] connections into a single data service to which they connect their LAN, usually through a router. In the example above (in which more than one EDGE SWITCH [1] is used to support more TELEPHONE STATIONS [3]) than can be supported by one EDGE SWITCH [1] alone), a low-cost aggregation router may be installed to load-balance LAN access to the public network evenly across the COMPUTER DATA INTERFACES [1.4]. To achieve this configuration would be a cable plug-in operation; the LAN side port of the aggregation router would be connected to the LAN hub; uplink ports on the aggregation router would connect it to the COMPUTER DATA INTERFACES [1.4].

Modes of Communication

[0174] Because all of the EDGE SWITCHES [1] are connected to an IP CARRIER NETWORK [6], and because each EDGE SWITCH [1] supports call sessions using SIP network signaling, the communications between EDGE SWITCHES [1] is for the most part peer-to-peer. Excepting the circumstance in which a call session has one of its endpoints in a network other than the IP CARRIER NETWORK [6] (i.e. PSTN), a SIP network signaling endpoint at one EDGE SWITCH [1] simply "invites" a SIP network signaling endpoint at another EDGE SWITCH [1] to join it in a call session. Usually, the participating endpoints negotiate to create voice or video (multimedia) streams between them.

[0175] Communications between TELEPHONE STATIONS [3] are usually based on E.164 dialing number addressing. The EDGE SWITCHES [1] perform the necessary conversion (using network-based resources) to dynamically associate a dialing number with an IP address, as required to set-up the SIP call session. Communications between SET-TOP BOXES [4] may be based on E.164 dialing number addressing or some other carrier-specific naming or addressing convention. SET-TOP BOXES [4] typically connect to a SIP APPLICATION SERVER and thus may use a different scheme.

[0176] Communications between COMPUTER WORKSTATIONS [5] are based on IP-based data communication protocols. The EDGE SWITCH [1] takes an active role in non-SIP data communications initiated by COMPUTER WORKSTATIONS [5] plugged into the COMPUTER DATA INTERFACE [1.4]. Data communications through

the EDGE SWITCH [1] are filtered through a programmable firewall feature set internal to the EDGE SWITCH [1] and Network Address Translation (NAT) services may also be applied. In addition, the EDGE SWITCH [1] performs QoS arbitration between all terminals competing for broadband access network transmission capacity, and as a result may attenuate the flow of IP packets available for data communications as transmission capacity is dynamically reserved for voice and video transmission.

Edge Switch Hardware Architecture

[0177] FIG. 5 depicts a generalized hardware architecture for the EDGE SWITCH [1]. The BROADBAND NETWORK INTERFACE [1.1] physically connects (OSI Layer 1) the EDGE SWITCH [1] to the BROADBAND ACCESS NETWORK [6.1]. Its ultimate role is to provide a datalink communication path through the BROADBAND ACCESS NETWORK [6.1] (OSI Layer 2) to the routed IP CARRIER NETWORK [6] (OSI Layer 3). Inside the EDGE SWITCH [1] itself, the BROADBAND NETWORK INTERFACE [1.1] ultimately presents an IP data path in the network layer to the IP ROUTING MODULE [1.2] (OSI Layer 3). The physical connection provided by the BROADBAND NETWORK INTERFACE [1.1] may serve as the DC POWER SOURCE [6.2] in some networks. Otherwise, the POWER SUPPLY [1.3] will require a DC POWER SOURCE [6.2] from the subscriber premise.

[0178] The COMPUTER DATA INTERFACE [1.4] and the VIDEO STREAMING DEVICE INTERFACE [1.5] provide physical interfaces for COMPUTER WORKSTATIONS [5] and SET-TOP BOXES [4] respectively. The TELEPHONE LINE INTERFACE [1.9] provides a physical interface for TELEPHONE STATIONS [3]. The IP ROUTING MODULE [1.2] provides for QoS routing of IP packets through the COMPUTER DATA INTERFACE [1.4] and the VIDEO STREAMING DEVICE INTERFACE [1.5]. It also provides for remote access to EDGE SWITCH [1] data exchange interfaces, management interfaces and feature activation interfaces through the IP data path to the IP CARRIER NETWORK [6].

[0179] The TELEPHONE LINE INTERFACE [1.9] converts device-level telephone signals (e.g. POTS telephone signals) to/from digitally encoded audio streams and digitally encoded device states (e.g. off-hook, on-hook, DTMF digits). The MEDIA STREAM CONTROLLER [1.7] interfaces the TELEPHONE LINE INTERFACE [1.9] and is responsible for routing these media streams to/from the PACKETIZATION COPROCESSOR [1.6], performing media format transcoding (as required) by applying digital signal processing algorithms to them. Digital signal processing algorithms run on the DIGITAL SIGNAL PROCESSOR [1.8]. The PACKETIZATION COPROCESSOR [1.6] takes responsibility for media stream transmission through the IP ROUTING MODULE [1.2] using RTP.

[0180] The CENTRAL PROCESSING UNIT [1.10] is responsible for supervising all network communications through the EDGE SWITCH [1], using the RANDOM ACCESS MEMORY [1.11] to execute an operating system,

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network communications protocol stacks, and CALL PROCESSING APPLICATIONS [1.23.2]. All of these software components are stored in a FILE SYSTEM [1.23] that uses the NON-VOLATILE MEMORY [1.12] as its storage medium. NON-VOLATILE MEMORY [1.12] is used to store a variety of databases, configuration files, and event histories.

Edge Switch Software Architecture

[0181] FIG. 6 depicts a software architecture for the EDGE SWITCH [1]. The software components and subsystems shown should be viewed as control logic to be layered over the EDGE SWITCH [1] hardware architecture depicted in FIG. 5. Certain software elements serve as hardware abstractions that maintain a direct control relationship over a particular hardware subcomponent. Other software elements support operations that do not directly relate to any particular hardware subcomponent, but in fact impart higher functionality to the EDGE SWITCH [1] as a whole.

QoS IP Routing Functions

[0182] The NETWORK ADAPATION LAYER [1.13] represents programmable logic, firmware, or software sub-components required to enable the BROADBAND NETWORK INTERFACE [1.1] to present IP connectivity to the IP ROUTING MODULE [1.2] in OSI Layer 3. The NETWORK ADAPATION LAYER [1.13] is designed to be maintained as a discreet subsystem apart from the IP ROUTING SYSTEM [1.14] so that it may be changed to support different OSI Layer 2 technologies without requiring commensurate changes to the IP ROUTING SYSTEM [1.14].

[0183] The IP ROUTING SYSTEM [1.14] is the control software required to enable the IP ROUTING MODULE [1.2] to operate. This software incorporates the IP protocol stack and is responsible for supporting all IP routing functions for the EDGE SWITCH [1], including QoS arbitration necessary to support sharing transmission capacity between real-time voice/video communications and common data transmission. Certain software or firmware sub-components of the IP ROUTING SYSTEM [1.14] may be responsible for packet labeling (or re-labeling), traffic shaping, flow control, and other QoS arbitration functions related to managing IP packet exchange between the IP ROUTING MODULE [1.2] and the routed terminal interfaces (i.e. COMPUTER DATA INTERFACE [1.4] and VIDEO STREAMING DEVICE INTERFACE [1.5]).

[0184] Certain software or firmware sub-components in of the IP ROUTING SYSTEM [1.14] system may run on the IP ROUTING MODULE [1.2] (i.e. downloaded firmware or programmable logic) while others may run on the CENTRAL PROCESSING UNIT [1.10], communicating with the IP ROUTING MODULE [1.2] in a device control capacity.

[0185] The IP ROUTING SYSTEM [1.14] incorporates a software abstraction of the IP ROUTING MODULE [1.2], supporting internal APIs necessary to enable IP communications by the RTP PROTOCOL STACK [1.15], the SIP PROTOCOL STACK [1.16], the HTTP PROTOCOL STACK [1.17], and the SNMP PROTOCOL STACK [1.18]. Routing services such as Network Address Translation and programmable firewall features are also supported through this abstraction.

Protocol Stacks for Network Communications

[0186] The RTP PROTOCOL STACK [1.15] runs primarily on the PACKETIZATION COPROCESSOR [1.6] so as to ensure consistently uninterrupted RTP media transmission through the network irrespective of the processing load on the CENTRAL PROCESSING UNIT [1.10]. The RTP PROTOCOL STACK [1.15] is used by the ABSTRACT TELEPHONE CONTROLLER [1.19] to support real-time voice communications by TELEPHONE STATIONS [3] plugged into the TELEPHONE LINE INTERFACE [1.9].

[0187] The SIP PROTOCOL STACK [1.16] runs on the CENTRAL PROCESSING UNIT [1.10] and is used by the ABSTRACT CALL MODEL [1.20] to support all SIP network signaling operations. Among other roles, it functions as the default SIP Proxy Server for all voice and video terminals plugged into the EDGE SWITCH [1], acting an intermediary for all SIP network signaling operations between those terminal devices and those in the network with whom they are communicating. FIG. 11 depicts this role of the SIP PROTOCOL STACK [1.16] to the extent that the DES as a system functions as a distributed SIP Proxy Server, using the DNS SERVER [10] as a centralized database to translate E.164 dialing numbers into IP addresses (as required to establish SIP call sessions in the ESN).

[0188] The HTTP PROTOCOL STACK [1.17] runs on the CENTRAL PROCESSING UNIT [1.10] and is used to provide secure, session-based access to the XML MGMT INTERFACE [1.21] by remote management applications and network-based applications. In a similar fashion, the SNMP PROTOCOL STACK [1.18] also runs on the CENTRAL PROCESSING UNIT [1.10] and provides a standards-based management interface to various DEVICE MGMT AGENT [1.22] and related data objects (i.e. SNMP Agents and SNMP Management Information Blocks).

Terminal Interfaces

[0189] The COMPUTER DATA INTERFACE [1.4] and the VIDEO STREAMING DEVICE INTERFACE [1.5] are physical, routed interfaces to the IP ROUTING MODULE [1.2]. This control logic in the IP ROUTING SYSTEM [1.14] will modulate IP packet flows to/from COMPUTER WORKSTATIONS [5] and SET-TOP BOXES [4] plugged into these interfaces. TELEPHONE STATIONS [3] plugged into the TELEPHONE LINE INTERFACE [1.9] ultimately present themselves to the EDGE SWITCH [1] software architecture through the ABSTRACT TELEPHONE CONTROLLER [1.19], which provides an abstract software control model for the MEDIA STREAM CONTROLLER [1.7] and the TELEPHONE LINE INTERFACE [1.9]. Logical media stream control operations, adjunct digital signal processing functions, and device-level control of TELEPHONE STATIONS [3] are made accessible to other internal EDGE SWITCH [1] software sub-components through an API presented by the ABSTRACT TELEPHONE CONTROLLER [1.19]. This API contains functions that enable the detection of device-level telephone signaling events (i.e. on-hook, off-hook, flash, DTMF digits, flash) originating from the TELEPHONE STATIONS [3] plugged into the TELEPHONE LINE INTERFACE [1.9]. These logical operations and functions supported by the API are realized by mapping them to physical operations supported by the MEDIA STREAM CONTROLLER [1.7] and the TELEPHONE LINE INTERFACE [1.9].

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