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(54) **MANAGING AND PROVISIONING VIRTUAL ROUTERS**

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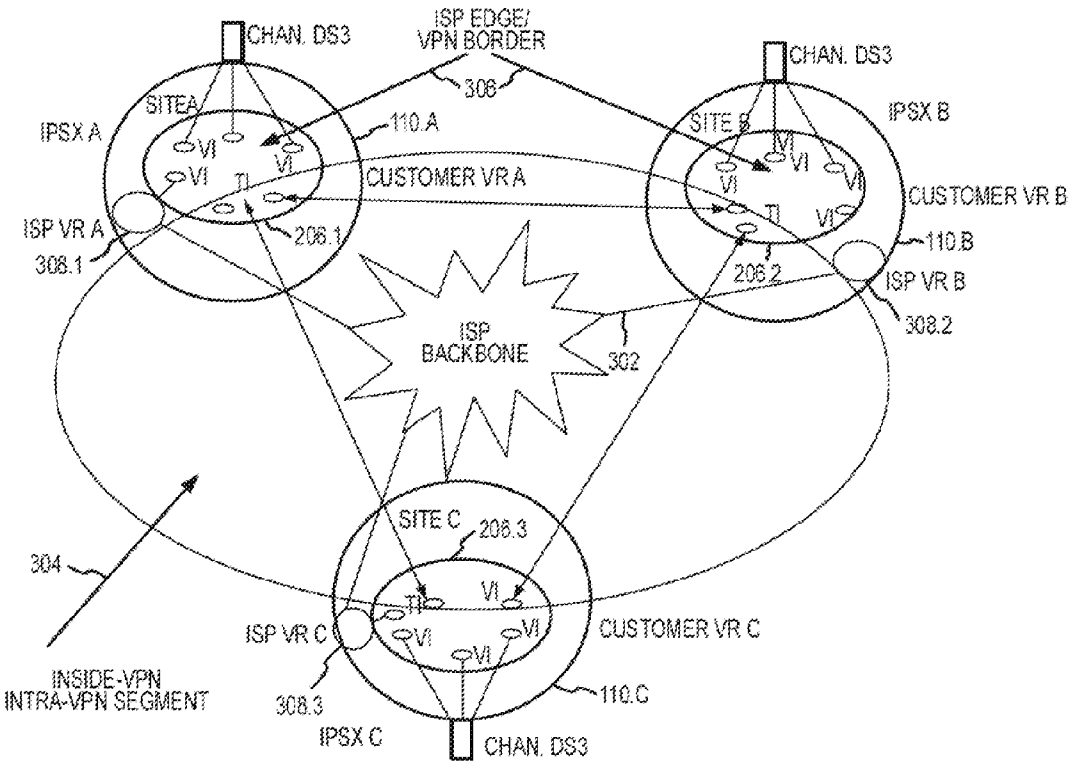
(57) **ABSTRACT**

Methods and systems are provided for provisioning and managing network-based virtual private networks (VPNs). According to one embodiment, routing information, including virtual private network (VPN) addresses reachable, for customer sites connected via service processing switches is learned or discovered. The routing information is disseminated among routers associated with multiple network-based customer VPNs for multiple customers. A routing configuration is generated for a network-based customer VPN based on the routing information and a global customer routing profile. Virtual routers (VRs) of the service processing switches are provisioned to support the customer VPN based on the routing configuration. A custom routing profile for the customer VPN is received that identifies one or more routing protocols to be used for one or more segments of the customer VPN. The customer VPN is automatically reconfigured by programmatically generating appropriate routing configurations for the VRs based on the routing information and the custom routing profile.



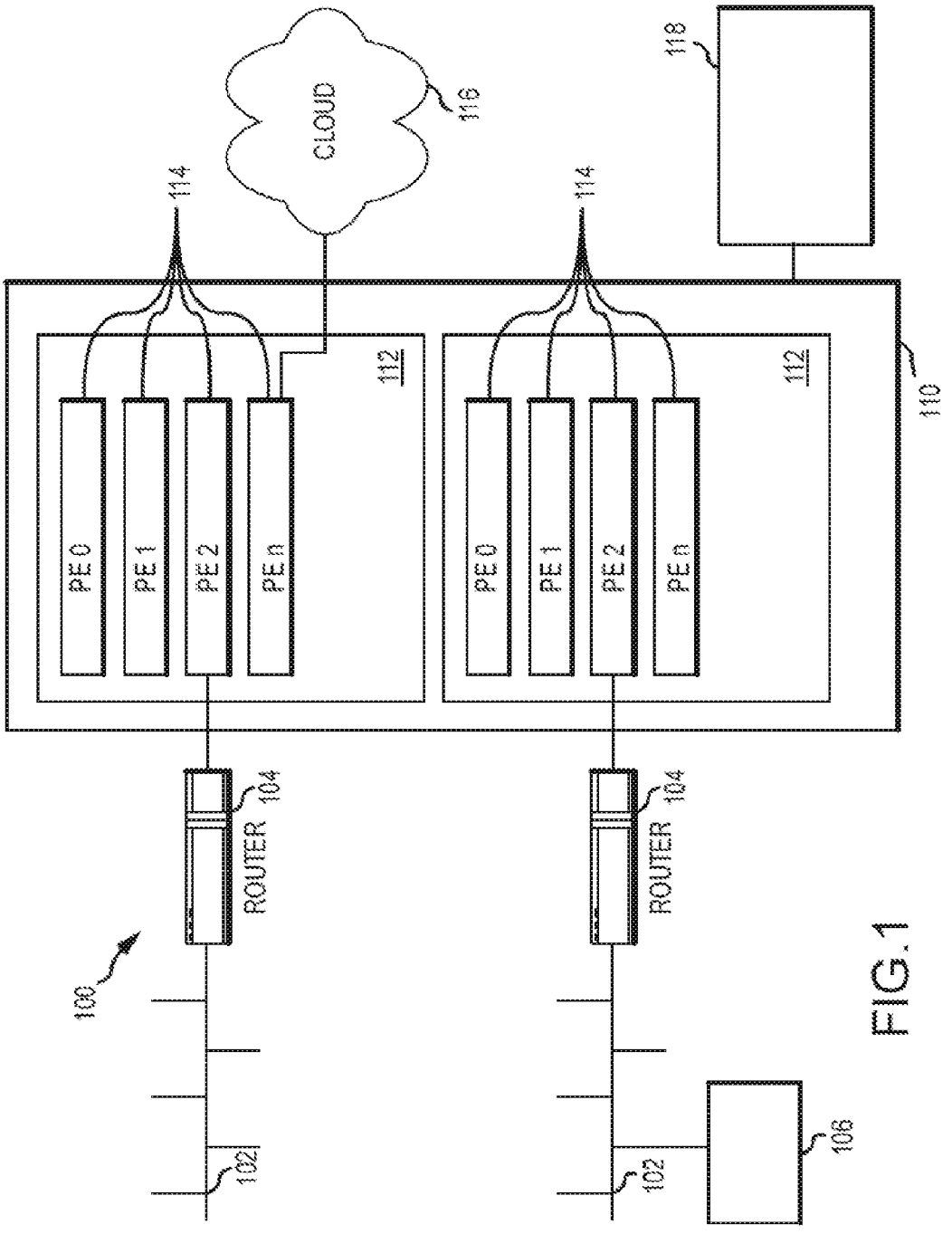

CLOUD
116
118
114
114
112
112
110
PE 0
PE 1
PE 2
PE n
PE 0
PE 1
PE 2
PE n
ROUTER
104
ROUTER
104
100
102
102
106

FIG. 1

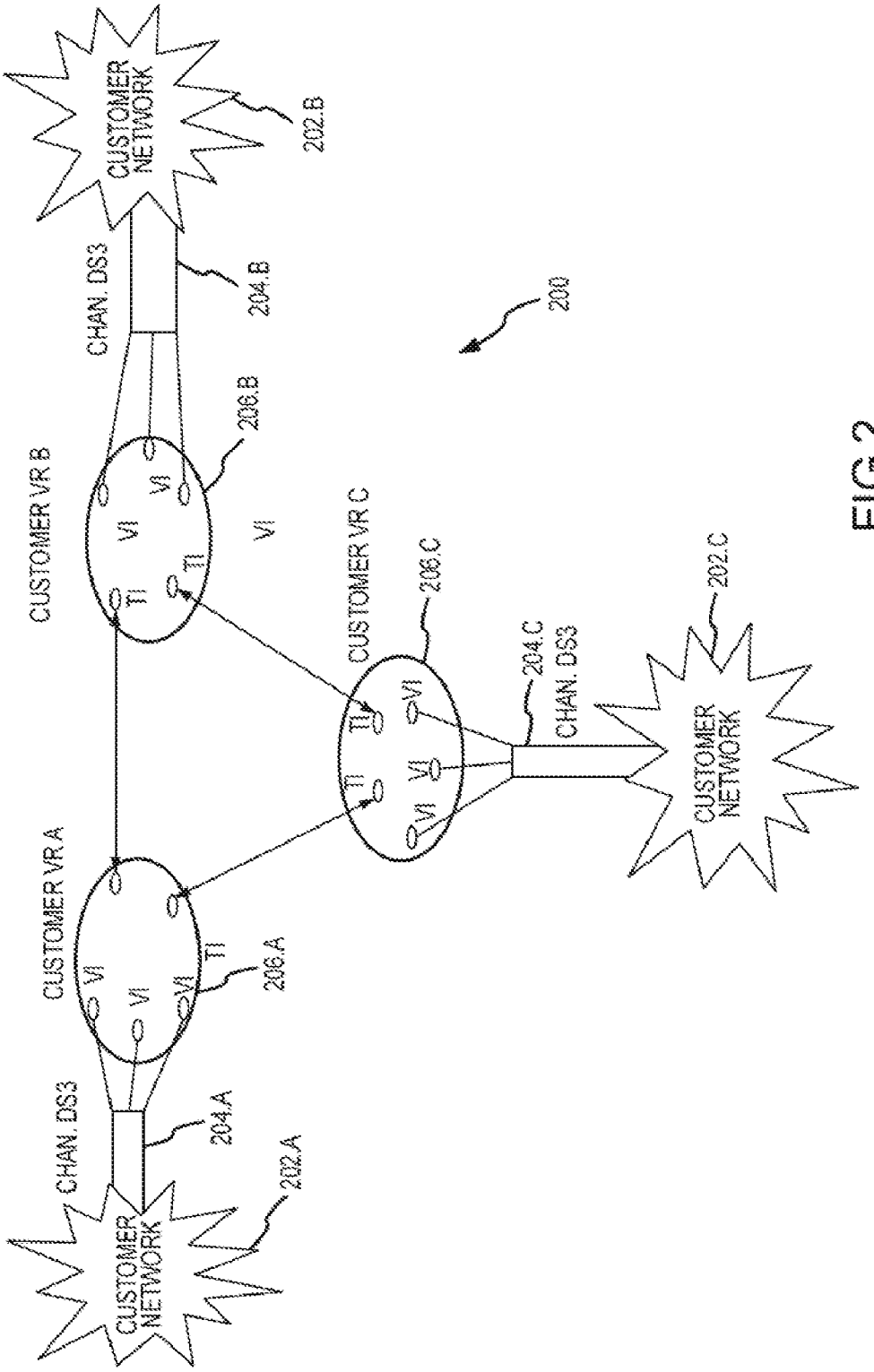

CUSTOMER NETWORK
202.B
CHAN. DS3
204.B
200
206.B
CUSTOMER VR B
VI
TI
VI
TI
VI
CUSTOMER VR C
206.C
TI
VI
VI
VI
204.C
CHAN. DS3
202.C
CUSTOMER NETWORK
CUSTOMER VR A
VI
VI
VI
TI
206.A
CHAN. DS3
204.A
202.A
CUSTOMER NETWORK

FIG.2

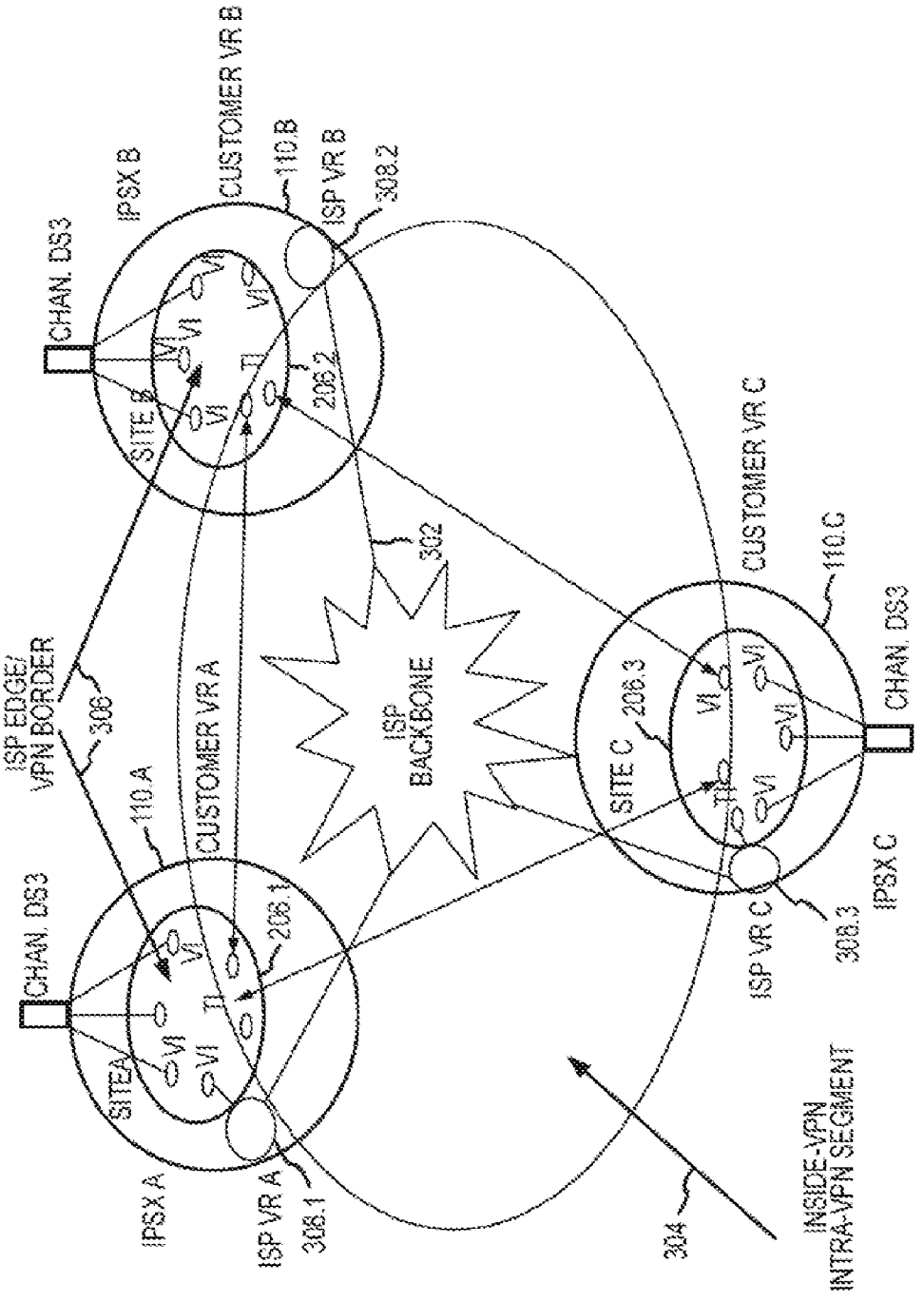

IPSX A
CHAN. DS3
SITE A
VI
T1
206.1
ISP VR A
306.1
110.A
CUSTOMER VR A
ISP EDGE/
VPN BORDER
306
IPSX B
CHAN. DS3
SITE B
206.2
ISP VR B
308.2
110.B
CUSTOMER VR B
ISP
BACKBONE
302
IPSX C
CHAN. DS3
SITE C
206.3
ISP VR C
308.3
110.C
CUSTOMER VR C
304
INSIDE-VPN
INTRA-VPN SEGMENT

FIG.3

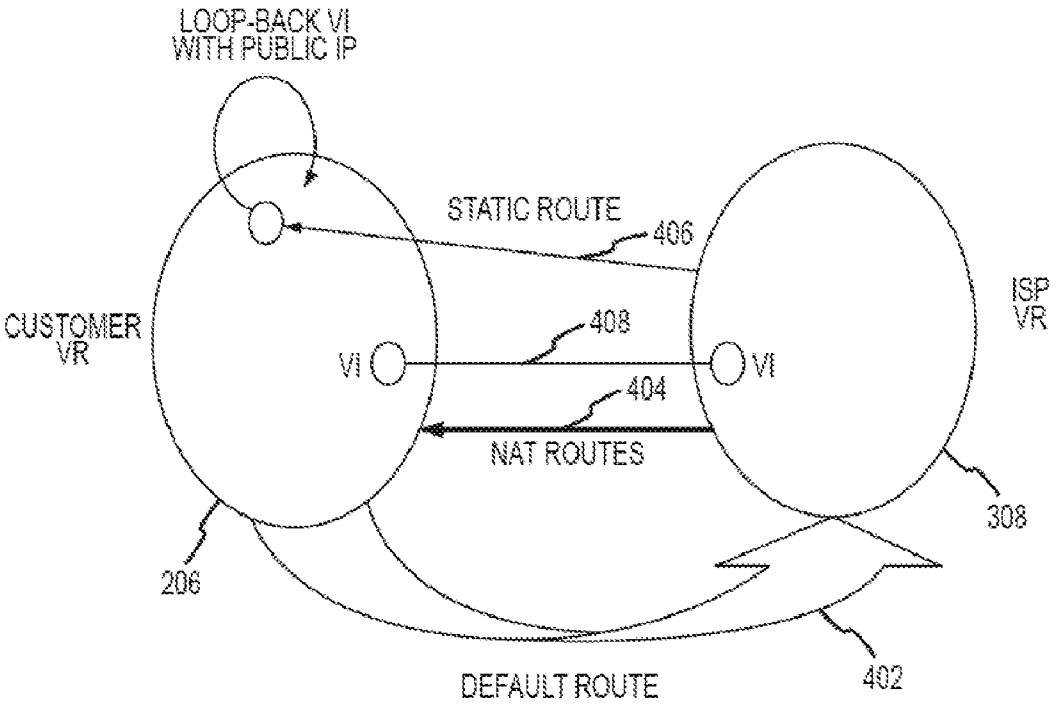

LOOP-BACK VI
WITH PUBLIC IP
STATIC ROUTE
406
CUSTOMER
VR
VI
408
VI
404
NAT ROUTES
ISP
VR
308
206
DEFAULT ROUTE
402

FIG.4

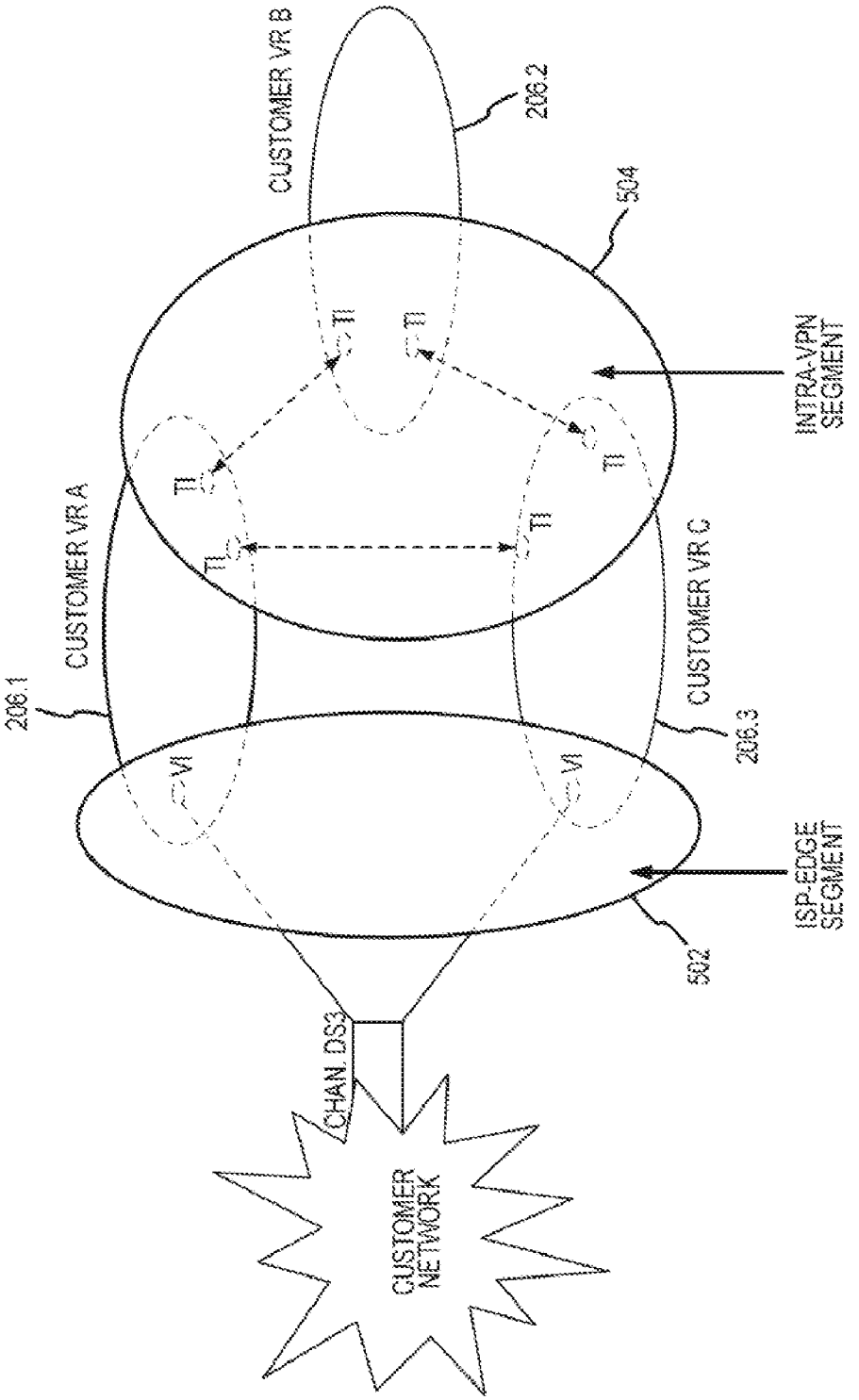

CUSTOMER VR B
206.2
504
INTRA-VPN SEGMENT
TI
TI
TI
TI
TI
TI
CUSTOMER VR A
206.1
CUSTOMER VR C
206.3
VI
VI
ISP-EDGE SEGMENT
502
CHAN_DS3
CUSTOMER NETWORK

FIG.5

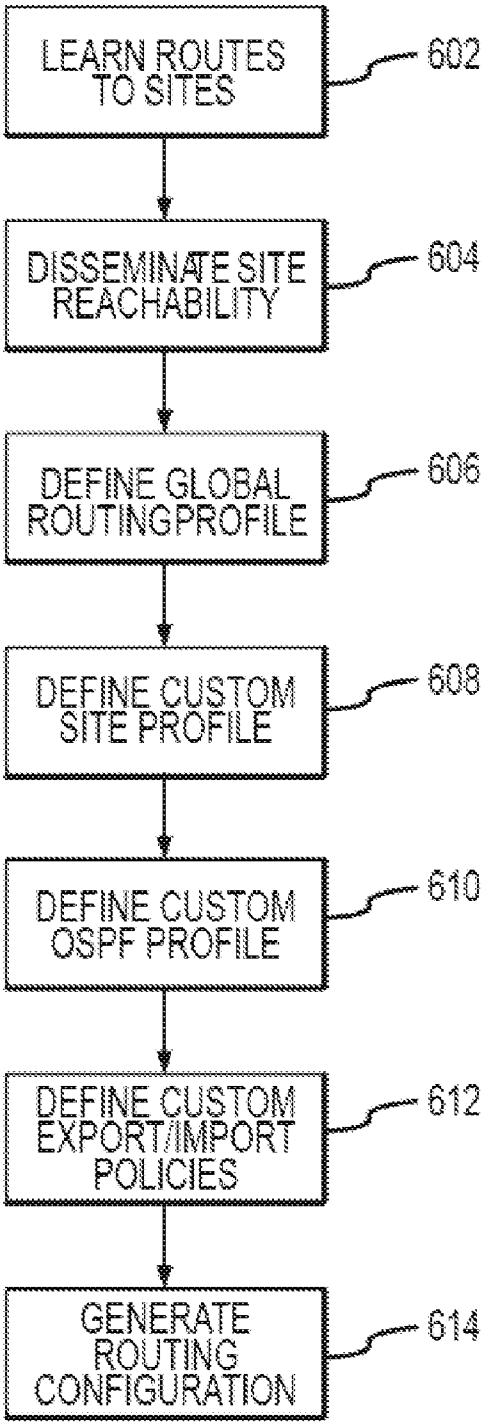

LEARN ROUTES TO SITES
602
DISSEMINATE SITE REACHABILITY
604
DEFINE GLOBAL ROUTINGPROFILE
606
DEFINE CUSTOM SITE PROFILE
608
DEFINE CUSTOM OSPF PROFILE
610
DEFINE CUSTOM EXPORT/IMPORT POLICIES
612
GENERATE ROUTING CONFIGURATION
614

FIG.6

MANAGING AND PROVISIONING VIRTUAL ROUTERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 13/022,696, filed Feb. 8, 2011, which is a continuation of U.S. patent application Ser. No. 12/637,140, filed Dec. 14, 2009, now U.S. Pat. No. 7,885,207, which is a continuation of U.S. patent application Ser. No. 11/616,243, filed Dec. 26, 2006, now U.S. Pat. No. 7,639,632, which is a divisional of U.S. patent application Ser. No. 09/663,485, filed on Sep. 13, 2000, now U.S. Pat. No. 7,272,643, all of which are hereby incorporated by reference in their entirety for all purposes.

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FIELD

[0003] Embodiments of the present invention relate generally to computer network routers, and more particularly to systems and methods of managing virtual routers.

BACKGROUND

[0004] The interest in the deployment of virtual private networks (VPNs) across IP backbone facilities is growing every-day. In general, VPNs fall into two categories: Customer Provided Equipment—(CPE) based VPNs and network-based VPNs.

[0005] With CPE-based VPNs, the ISP network provides only layer 2 connectivity to the customer. The CPE router takes ownership of setting up tunnels and handling routing with other sites. Network-based VPNs consist of a mesh of tunnels between ISP routers. They also have the routing capabilities required to forward traffic from each customer site. Each ISP router has a VPN-specific forwarding table that contains VPN member sites. The benefit offered by network-based VPNs is that the ISP is responsible for routing configuration and tunnel setup. In addition, other services, such as firewall, Quality of Service (QoS) processing, virus scanning, and intrusion detection can be handled by a small number of ISP routers. New services can be introduced and managed without the need to upgrade CPE devices.

[0006] There are typically three steps to building a VPN's infrastructure:

[0007] 1) Define a topology and create tunnels using IPSec, LT2P, PPTP, GRE, or MPLS.

[0008] 2) Configure routing on the edge routers to disseminate site- and intra-VPN reachability information.

[0009] 3) Enable such services as firewall, QoS, and so forth.

[0010] Usually, IP network managers use the following model for building and maintaining their networks:

[0011] 1) With the help of some network experts, design the network.

[0012] 2) Use the command line interface (CLI) or ASCII configuration files to define the routing configuration.

[0013] 3) Use trial-and-error method to determine a working solution for the network configuration.

[0014] 4) Manually manage configuration files for routers.

[0015] The process of building or changing a network requires significant manual effort, and is slow, expensive, and error-prone. For ISPs that plan to provide VPN services, this model for provisioning VPNs is problematic. ISPs need to configure routing for VPNs, each of which can be considered separate networks.

[0016] As noted above, building and managing one network is difficult, the problem is made much worse when the ISP must build and manage thousands of networks. For ISPs to succeed at this, a facilitation framework is required.

SUMMARY

[0017] Methods and systems are described for simplifying the provisioning and management of network-based virtual private networks (VPNs). According to one embodiment, routing information for each of multiple customer sites connected via multiple service processing switches is learned or discovered. The routing information includes virtual private network (VPN) addresses reachable at each customer site. A subset of the routing information is disseminated among routers associated with multiple network-based customer VPNs for multiple customers. A routing configuration is generated for a network-based customer VPN based on the routing information and a global customer routing profile of the network-based customer. Virtual routers (VRs) distributed among the service processing switches and partitioned to the network-based customer VPN are provisioned to support the network-based customer VPN based on the routing configuration. A custom routing profile for the network-based customer VPN is received that identifies one or more routing protocols to be used for one or more segments of the network-based customer VPN. The network-based customer VPN is automatically reconfigured by programmatically generating appropriate routing configurations for the VRs based on the routing information and the custom routing profile.

[0018] Other features of embodiments of the present invention will be apparent from the accompanying drawings and from the detailed description that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Embodiments of the present invention are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

[0020] FIG. **1** is a block diagram of the hardware and operating environment in which various embodiments of the present invention can be practiced;

[0021] FIG. **2** is a diagram illustrating an exemplary Virtual Private Network (VPN), which may be used in discussing various embodiments of the present invention;

[0022] FIG. **3** is a diagram illustrating further details of an exemplary Virtual Private Network (VPN), which may be used in discussing various embodiments of the present invention;

[0023] FIG. **4** is a diagram illustrating Inter-VPN reachability in accordance with various embodiments of the present invention;

[0024] FIG. **5** is a diagram illustrating dynamic intra-VPN routing in accordance with various embodiments of the present invention; and

[0025] FIG. **6** is a flowchart illustrating a method for provisioning a router configuration according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0026] In the following detailed description of exemplary embodiments of the invention, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific exemplary embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical, electrical and other changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense.

[0027] In the Figures, the same reference number is used throughout to refer to an identical component, which appears in multiple Figures. Signals and connections may be referred to by the same reference number or label, and the actual meaning will be clear from its use in the context of the description.

[0028] The detailed description is divided into multiple sections. In the first section the hardware and operating environment of different embodiments of the invention is described. In the second section, the software environment of varying embodiments of the invention is described. In the final section, a conclusion is provided.

Hardware and Operating Environment

[0029] FIG. **1** is a diagram of the hardware and operating environment in conjunction with which embodiments of the invention may be practiced. The description of FIG. **1** is intended to provide a brief, general description of suitable computer routing hardware and a suitable computing environment in conjunction with which the invention may be implemented. Although not required, the invention is described in the general context of computer-executable instructions, such as program modules, being executed by a computer, such as a personal computer or a server computer. Generally, program modules include routines, programs, objects, components, data structures, etc., that perform particular tasks or implement particular abstract data types.

[0030] As shown in FIG. **1**, the system **100** includes a service processing switch **110**, access routers **104**, service management system **118**, and customer network management system **106**. In some embodiments, service processing switch **110** provides switching, routing and computing resources that can be allocated by a service provider to customers. In one embodiment, the service processing switch **110** is the IPSX 9000 service processing switch from CoSine Communications, Inc. However, the invention is not limited to any particular switch, router or service processing hardware.

[0031] Service processing switch can contain one or more blades **112**. In some embodiments of the invention, blades **112** have a type associated with them. Examples of blade types include, processing functions such as network blades, control blades, trunk blades, and processor blades. Network blades provide interfaces to different types of networks. Control blades provide system management and accounting functions to the service processing system **110**. Trunk blades provide access to high speed trunk networks. Processor blades provide general purpose computer processors that in some embodiments of the invention provide firewall, intrusion detection, or directory services. Blades are communicably coupled to one another, in one embodiment a packet ring is used to couple the blades.

[0032] In some embodiments, each of blades **112** includes one more processing elements **114**. Processing elements **114** include CPU and memory that provide computing resources for the blade. The invention is not limited to any particular number of processing elements on a blade, nor is the invention limited to any particular number of blades in a service processing switch **110**.

[0033] Service processing system **110** is typically communicably coupled to a network **116**, for example the Internet. Network **116** can also be a Wide Area Network (WAN), a Local Area Network (LAN), or a private network.

[0034] Service processing system **110** is also typically communicably coupled to a plurality of customer networks **102** via customer access routers **104**.

[0035] Service management system **118** hosts software that is used to configure and control the operation of service processing switch **110**. In one embodiment of the invention, the service management system is a SPARC system available from Sun Microsystems, Inc. running the In Vision product from CoSine Communications, Inc. Service management system **118** can be used to allocate resources within service processing switch **110** to various customers. In one embodiment of the invention, service management system **118** communicates with service processing switch **110** using the Simple Network Management Protocol (SNMP). The operation of service management system **118** will be described in further detail in the sections that follow.

[0036] Customer network management system **106** hosts software that configures and controls the resources within service processing switch **110** that have been allocated to the particular customer. The operation of service management system **118** will be described in further detail in the sections that follow.

[0037] Those skilled in the art will appreciate that the invention may be practiced with other routing system hardware configurations besides those described above.

Software Environment

[0038] Embodiments of the present invention include a software environment of systems and methods that provide a mechanism for simplifying the provisioning and management of Virtual Private Networks (VPNs) and Virtual Routers (VRs) within a service processing switch. Various embodiments of the present invention provide a policy-based mechanism for network provisioning. Thus, a service provider, for example, an Internet Service Provider (ISP), managing a service processing switch can create various service policies, which are used in defining VPN profiles. These profiles are used to automatically generate tunnels, routing, and other service configurations for VPNs. Resources within switch **110** such as blades and processing elements are allocated by a service provider to one or more customers, who then can

configure those elements allocated to it. Configuration from the service provider's perspective, and from the customer's perspective can be driven based on profiles.

[0039] FIG. **2** provides an illustration of a VPN as used in various embodiments of the invention. A VPN is typically a logical grouping of virtual routers (VRs) **206**. The connectivity between VPNs and customer sites **202** is provided by means of virtual interfaces (VIs). Users can create VIs and connect them to customer sites or to VIs of other VRs. The virtual connection can also be configured to be a tunnel interface (TI) to a type of secured tunnel, such as an IPSec tunnel. Customer sites can be connected via a network interface **204**, which can be a leased line interface such as DS3. The invention is not limited to any particular type of network interface.

[0040] In some embodiments of the invention, two types of virtual routers are supported: Customer VRs and ISP VRs. Customer VRs are used to build customer VPNs, and ISP VRs are used to build ISP VPN. The ISP VPN is connected to an ISP backbone network **310** (FIG. **3**). In this framework, each ISP needs only one ISP VPN. Customer VRs can be connected to the ISP VPN by means of VIs. Every virtual router can use one or more routing protocols, including STATIC, RIP, OSPF, and BGP, to disseminate reachability information. For routing purposes, every VPN based on this framework can be treated as an extension of the customer network.

[0041] Various embodiments of the invention allow network managers to define profiles. The profile information may be used to automatically generate the routing configuration for a VPN. In some embodiments, to profile the routing on a VPN, a customer VPN is divided into three segments, which are illustrated in FIG. **3**.

[0042] ISP-Edge segment **306** is a VPN segment that connects the VPN to customer sites. This segment includes all virtual interfaces connected to logical interfaces and tunnel interfaces whose remote end is outside the VPN. This segment is used for disseminating customer site reachability information.

[0043] Inside-VPN segment **304** (also referred to as an Intra-VPN segment) is a VPN segment that provides connectivity among different VRs **206**. This segment is used to disseminate intra-VPN reachability information.

[0044] Inter-VPN segment **302** is a VPN segment that connects different types of VPNs; for example, the interfaces that connect a customer VPN with an ISP VPN.

[0045] It is desirable to identify segment types, because it provides a mechanism for generating profiles that can be optimized depending on the segment type.

Profile-Based Routing Configuration

[0046] FIG. **4** illustrates how the routing needs of the Inter-VPN segment **302** are taken care of at the time a VR is created. When a customer VR **206** is created, the user is given the option to automatically connect the VR with an ISP VR **308**. At that time, service management system **118** (FIG. **1**) also creates a default route **402** on the customer VR **206** and a static route **406** on the ISP VR **308**, which accommodates customer VR **206** to ISP VR **308** connectivity. In this model, for all network address translation (NAT) addresses **404**, the user must add static routes on the ISP VPN.

[0047] The profile discussed here takes care of the first two VPN segments: ISP-Edge **306** and Intra-VPN **304**. Given a VPN's routing requirements, there are typically three routing aspects that are considered:

[0048] 1) The routing protocol that should be turned on a virtual interface in a VR.

[0049] 2) When and how to redistribute routes between various routing protocols.

[0050] 3) When enabling a routing protocol on a router or interface, the routing parameters to use for optimizing performance.

[0051] Service management system **118** (FIG. **1**) uses VPN profile data to automatically generate the required routing configuration. In some embodiments of the invention Border Gateway Protocol (BGP) is excluded as a possible choice for configuring customer VPNs. There are a few reasons for this. First, there are only two cases in which BGP would be used in a VPN environment. ISP-VPNs might use BGP to talk to the Internet core. Also, if a VPN connects two very large customer sites, IBGP might be needed for the Intra-VPN segment to ensure scalability. There will generally be very few ISP VPNs (in most networks, there is only one), and it's unlikely that a VPN will be used to connect two or more large sites.

[0052] The second reason for excluding BGP from the profile is the VR-specific customization that is required to make BGP work in a VPN environment. Because BGP connects ISP VRs to the ISP core, a careful selection of export and import policies is needed to minimize the number of routes in each ISP VR. It is very difficult to represent this type of configuration by means of a generic routing profile. Service management system **118** (FIG. **1**) provides an interface to configure BGP on VRs. This interface allows user to enable BGP on a VR, set its BGP neighbors, and add import and export policies.

[0053] In some embodiments of the invention, the profile defines a simple routing configuration, that is, static routing for the Intra-VPN segment. Thus static routing will be used to communicate with each customer site. This configuration is desirable because it puts a minimum load on the device, thus increasing the number of VPNs that can be managed by each service processing switch **110**.

[0054] There are two issues with static routing. First, ISPs need to manage static routes for each customer. As new subnets are added to customer networks and old ones are removed, the static routes corresponding to these subnets should be added or removed in the corresponding VPNs. In some embodiments, this problem can be solved by having service management system **118** (FIG. **1**) take ownership of automatically managing static routes based on the customer site subnet information. In these cases, customers can directly add or remove subnet information using tools such as the customer network management system **106** (FIG. **1**). This capability will transfer the ownership of managing routing to customers.

[0055] A second issue with static routing is that the routing by definition is STATIC. If a site interface is down, traffic cannot be re-routed to an alternate path. A partial solution to this problem can be provided by allowing customer to disable routing on a site that is down. This can be done by means of a customer network management system **106** (FIG. **1**). In this scenario, service management system **118** (FIG. **1**) would remove the static routes from the network that belong to the site that is down. This action would allow the traffic to go through the backup path.

[0056] To resolve the two issues described above, various embodiments of the present invention provide a mechanism for a user to choose more advanced routing options in profiles.

For smaller sites, a viable option is Routing Information Protocol (RIP), while for large sites operators might choose Open Shortest Path First (OSPF) gateway protocol. Dynamic routing transfers the burden of managing route changes from the network manager to the device. If a user selects dynamic routing at the edge, then the service management system will also have to use dynamic routing to disseminate Intra-VPN reachability information. FIG. **5** illustrates this scenario. If a site link to virtual router A **206.1** is down, virtual router B **206.2** will know that the traffic going through that link needs to be rerouted to virtual router C **206.3** only if dynamic routing is specified for Intra-VPN segment **504**.

[0057] If all the sites (ISP-Edge segment) are using static or RIP routing, service management system **118** will allow the user to choose between RIP and OSPF for Intra-VPN routing. The user will typically select RIP if there are relatively few VRs in the VPN. Because OSPF is more scalable, it is a logical choice for bigger VPNs. If a user decides to run OSPF at a site edge, it is desirable to select OSPF for the Intra-VPN segment.

[0058] This section has described the various software components in a system that provides for the automatic generation and provisioning of routing configurations. As those of skill in the art will appreciate, the software can be written in any of a number of programming languages known in the art, including but not limited to C/C++, Java, Visual Basic, Smalltalk, Pascal, Ada and similar programming languages. The invention is not limited to any particular programming language for implementation.

Methods for Performing Profile-Based Routing Configuration

[0059] In the previous section, a system level overviews of the operation of exemplary embodiments of the invention were described. In this section, the particular methods of the invention performed by an operating environment executing an exemplary embodiment are described by reference to a flowchart shown in FIG. **6**. The methods to be performed by the operating environment constitute computer programs made up of computer-executable instructions. Describing the methods by reference to a flowchart enables one skilled in the art to develop such programs including such instructions to carry out the methods on suitable computers (the processor of the computer executing the instructions from computer-readable media). The method illustrated in FIG. **6** is inclusive of the acts required to be taken by an operating environment executing an exemplary embodiment of the invention.

[0060] The method begins at block **602** when a system executing the method learns, or discovers, the current routes to sites connected via the service processing switch **110** (FIG. **1**). To build or include new sites in a VPN, each edge router must learn the routes to all sites connected to all the edges in the network. An edge in a network is a boundary between two routers, an edge router is a typically network device that routes data between one or more local area networks backbone network. Two components of routing information are typically needed for the VPN:

[0061] 1) Site Reachability Information: Each edge router needs to learn the set of VPN addresses and address prefixes reachable at each site. The reachability information needed by the Customer Provided Equipment (CPE) router depends on site configuration. Customer sites are characterized into two categories: stub sites and non-stub sites. The CPE routers of stub sites have default routes pointing to an ISP edge router, while the CPE router of non-stub site do not, and therefor need to know the set of non-local destinations reachable via that link. Usually, if a VPN also provides Internet connectivity to a site and there is no backdoor connection between this and any other site, it is a stub site.

[0062] 2) Intra-VPN Reachability Information: Once an edge router has learned the set of prefixes associated with each of its customer site's links, this information must be disseminated to each other router in the VPN.

[0063] After learning routes to sites, the system disseminates site reachability information (block **604**). Various embodiments of the invention employ different mechanisms to disseminate the information. In one embodiment, static configuration is used. In static configuration, all the subnets associated with each customer site are manually configured into the VPN. To increase the manageability of this information, customer network management (CNM) **116** (FIG. **1**) tools can be enhanced to allow customers to directly add and remove subnet information from the VPN. The subnet information can be used to automatically create the static routes in the VPN. In this case, the customer also needs to add static routes to the CPE routers of non-stub sites.

[0064] In an alternative embodiment, directory lookup is used to disseminate the site routing information. A central directory server can maintain the identities of edge routers associated with a VPN, and the set of customer site links bound to the VPN per edge router. Each edge router can query this information using some defined mechanism (for example, LDAP) upon startup. This mechanism requires some kind of database synchronization mechanism in order for all edge routers to learn the addition and deletion of sites from the VPN.

[0065] In a further alternative embodiment, a routing protocol can be run between the CPE edge router and the ISP edge router to exchange reachability information. This allows an ISP edge router to learn the prefixes that can be reached at a customer site, and enables a CPE router to learn the destinations that can be reached via the provider network.

[0066] In a still further embodiment, if a CPE router runs Multiprotocol Label Switching (MPLS), the MPLS Label Distribution Protocol (LDP) can be extended to convey the set of prefixes at each stub site, together with the appropriate labeling information.

[0067] In addition to the above, several mechanisms for Disseminating Intra-VPN Reachability Information can be used. In one embodiment employing static configuration, the service management system **118** can use the subnets configured for each site to automatically create static routes for dissemination of intra-VPN reachability information.

[0068] In an alternative embodiment, directory lookup information is used. In addition to VPN membership information, a central directory can maintain a listing of the address prefixes associated with each end point.

[0069] In a further alternative embodiment, each edge router runs an instance of a routing protocol on each VPN to disseminate intra-VPN reachability information. Using this mechanism, both full-mesh and arbitrary, VPN topologies can be easily supported.

[0070] A still further alternative embodiment uses a Link Reachability Protocol. Here each edge router can run a link reachability protocol carrying the necessary information. This protocol runs across the tunnel between the two edge routers. The two preferred choices for this approach are a

variation of MPLS LDP and IBGP. The link reachability protocol-based schemes can support only fully meshed VPNs.

[0071] In yet a further alternative embodiment, site reachability information is disseminated by Piggybacking on IP Backbone Routing Protocols. The set of address prefixes associated with each stub interface can also be piggybacked into the routing advertisements from each edge router and propagated through the network. Other edge routers extract this information from received route advertisements. This scheme typically requires that intermediate routers cache intra-VPN routing information to propagate the data further. This also has implications for the level of security possible for intra-VPN routing information.

[0072] In addition to learning and disseminating site reachability information, a global routing profile can be defined (block **606**). In one embodiment of the invention, the global routing profile includes the following parameters:

[0073] a. Routing administration status

[0074] b. Routing protocol for Intra-VPN segments

[0075] c. Default routing protocol at the ISP edge. All the customer sites will generally inherit this.

[0076] d. Default site type: stub or non-stub: Stub sites have a default route going toward the ISP VPN (Internet). For stub sites, there is no need to export routes from the VPN. This information is used in creating default export and import policies.

[0077] e. If the routing protocol for the Intra-VPN segment is OSPF, define the OSPF profile topology type.

[0078] When a site is added, it inherits the routing configuration from the routing profile.

[0079] In addition, the system provides for the definition of a custom site profile (block **608**). Multiple types of site information can be configured. First, if the site routing profile needs to be customized, the user may do so. Second, if a user wants static routing at the edge, the network subnets that are associated with the site must be provided. This configuration will allow the service management system to automatically create static routes. In one embodiment of the invention, the site profile contains following parameters:

[0080] a. Routing Protocol at the ISP edge

[0081] b. Site Type: stub or non-stub

[0082] c. OSPF Area ID: If OSPF is enabled at the edge

[0083] d. Site subnets.

[0084] In addition, a custom OSPF profile can be defined (block **610**). When a user configures a routing profile, service management system **118** (FIG. **1**) automatically generates OSPF, RIP, and static profiles, if needed. In many cases, the user will want to customize the generic OSPF profile. The user can customize the generated profile using a policy-based profile configuration workflow. The workflow includes the following features:

[0085] 1) The user can define custom OSPF areas. He only needs to configure what VRs are included in what areas; Service management system **118** (FIG. **1**) generates the required configuration for each VR and VI.

[0086] 2) The user can define a route aggregation policy for an OSPF area; Service management system **118** (FIG. **1**) will auto-generate this configuration for all the VRs in that area.

[0087] 3) By default, Service management system **118** (FIG. **1**) generates one VR routing parameter policy, which applies to all VRs, and three VI routing parameter policies, which apply to tunnel interfaces, customer site edges, and VI-VI connections. When routing configuration is generated, these policies are used to define routing parameters. The user can make changes in any of these policies, or create his own policies and assign them as defaults. The user also can define policies and set them to be applied on a set of VRs or VIs. Service management system **118** (FIG. **1**) allows users to individually customize parameters for a VR or VI.

[0088] When configuring OSPF for intra-VPN segment, the service management system cannot use the same guidelines as those used in setting up a normal OSPF network, because each router in a VPN is a virtual router. To optimize performance, it is desirable to minimize the size of the routing table. This can be accomplished by keeping the OSPF areas small. In a normal OSPF network, the network manager would not let the size of an OSPF area grow beyond 50-60 routers. With a VPN, it is desirable to not let the OSPF area grow beyond 20-25 VRs. The larger the OSPF area, the higher the load on each VR, and hence the fewer the VRs that can be created on the service processing switch. As a result, it is not desirable to make a complete mesh of all the VRs in a large VPN. The user should use a custom OSPF topology and create areas of reasonable size to ensure scalability and stability of the OSPF network.

[0089] The system also provides for the definition of custom export/import policies (block **612**). Using the router and site profile defined above, service management system **118** (FIG. **1**) generates default policies necessary for different routing protocols to talk to each other. In some situations, custom export and import policies are needed to control access to critical networks. The system allows users to add custom export and import policies.

[0090] Based on the site reachability information and/or the global and custom profiles described above, the service management system generates routing configuration (block **614**). Described below are exemplary items that may be considered during the generation of the configuration:

[0091] The user can only configure one protocol for the Intra-VPN segment. This configuration is used to configure the routing on all the interfaces that connect one VR to another in the same VPN. In most cases, this takes care of all tunnel interfaces.

[0092] If the user selects static routing for a site, service management system **118** (FIG. **1**) will auto-generate one static route per site subnet on the local VR. If the routing for the Intra-VPN segment is also static, service management system **118** (FIG. **1**) will also generate one static route per subnet on each remote VR. Auto-generation of static routes assumes a meshed-topology for the VPN. If the topology is not meshed, some additional configuration may be needed for the routing to work.

[0093] If dynamic routing is selected for the Intra-VPN segment, service management system **118** (FIG. **1**) auto-generates export policies to disseminate site reachability information to other VRs.

[0094] For a non-stub site that is using dynamic routing to communicate with the VPN, service management system **118** (FIG. **1**) will create an export policy to inject all the routes learned from the Intra-VPN segment's routing into the customer network.

[0095] If the user selects a custom OSPF topology for the Intra-VPN segment, he does not have to explicitly assign an area ID for each interface. Service management sys-

tem **118** (FIG. **1**) automatically interprets this information from the area configuration.

[0096] Once the profile is set, Service management system **118** (FIG. **1**) automatically handles the routing configuration for the addition and deletion of VRs and VIs. For example, if standard OSPF routing has been selected for the Intra-VPN segment, whenever the user creates an IPSec tunnel connecting two VRs, OSPF will be enabled with area ID 0.0.0.0.

[0097] If a VPN is using only one routing protocol for the Intra-VPN segment, service management system **118** (FIG. **1**) can discover routing profiles from the device configuration.

[0098] Service management system **118** (FIG. **1**) supports explicit two-phase provisioning of routing profile configurations. In the first phase, the user makes changes to the routing profile and saves them in the database. In the second phase, the user commits the profile to the network. In this phase, the server translates delta changes in the profile configuration into a required low-level configuration and pushes it to appropriate devices.

[0099] Service management system **118** (FIG. **1**) allows users to temporarily remove routing configurations from the device. Users can do this by providing administration status attributes for the routing profile. Setting this attribute to a "disabled" state and committing the profile removes configurations from the device. Routing can be turned on again by setting the admin status to "enabled."

[0100] As can be seen from the above, the generated and customized policies can act as templates that can be applied to particular VPNs, particular VRs, or groups of VRs. For example, assume an existing policy has been changed or further customized. In one embodiment of the invention, the user is presented with a list of VRs or VPNs that were configured with the existing policy. The user can then select the VRs to which the new policy should be applied.

[0101] Similarly, assume that the user wishes to change the policy for a particular VR. In one embodiment of the invention, the user selects the desired VR, and then selects a new policy to be applied to the VR. The new policy can then be applied immediately, or it can be applied at a later scheduled time.

[0102] In addition, the policies can be used as a differentiator in providing VPN services. If user selects STATIC routing for ISP-Edge and Intra-VPN segments, the service processing switch does not need to run any routing instances per customer VR. On the other hand, if a user has chosen to run dynamic routing for Intra-VPN and ISP edge segments, the switch may have to run instances of routing protocols such as OSPF and RIP. Running routing instances on virtual routers consumes both processing power and memory on the processing elements and blades. The demand on the resources will depend on the size of VPN and its interaction with various customer sites. An ISP can recover the cost of the increased resource usage, by using routing as a differentiator in providing VPN services. There are few methods of providing services:

[0103] 1) Allow user to select the routing protocol per site: STATIC, RIP, or OSPF. Based on the site configuration, ISP can automatically configure routing protocol for intra-VPN segment. The cost of the service should be the lowest for STATIC and the highest for OSPF.

[0104] 2) Define a few fixed routing profiles and sell them as a part of service packages such as Gold, Silver, and Bronze. For instance, Gold will allow user to select OSPF for intra-VPN as well as ISP edge segment. Silver will allow user to configure OSPF for intra-VPN segment, while RIP for ISPF edge. The bronze package will permit customer to configure STATIC for ISP edge as well as Intra-VPN segment.

[0105] 3) Provide additional services as part of a profile, For example, include firewall, intrusion detection, network address translation, proxy services, or other network services as part of a differentiated service package. The service can then be included in profiles defined as part of the service package, and excluded from profiles for customers that do not pay for the service.

CONCLUSION

[0106] Systems and methods for generating and provisioning router configurations are disclosed. Embodiments of the present invention provide advantages over previous systems. For example, embodiments of the present invention provide a mechanism for easily and rapidly generating configuration information for large numbers of virtual routers and virtual private networks based on profiles. In addition, embodiments of the present invention separate the connectivity and routing needs of each VPN, thus significantly reducing the complexity of the network design. This separation also enables layering of advanced services to specific subscribers' networks. Visibility of subscriber services is end-to-end. The topology and routing needs of each VPN depend on the number and size of customer sites.

[0107] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement, which is calculated to achieve the same purpose, may be substituted for the specific embodiments shown. This application is intended to cover any adaptations or variations of the present invention.

[0108] The terminology used in this application is meant to include all of these environments. It is to be understood that the above description is intended to be illustrative, and not restrictive. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. Therefore, it is manifestly intended that this invention be limited only by the following claims and equivalents thereof.

What is claimed is:

1. A method comprising:

learning or discovering routing information for each of a plurality of customer sites connected via a plurality of service processing switches, the routing information including virtual private network (VPN) addresses reachable at each customer site of the plurality of customer sites;

disseminating a subset of the routing information among routers associated with a plurality of network-based customer VPNs for a plurality of customers;

generating a routing configuration for a network-based customer VPN of the plurality of network-based customer VPNs based on the routing information and a global customer routing profile of the network-based customer;

provisioning a plurality of virtual routers (VRs) distributed among the plurality of service processing switches and partitioned to the network-based customer VPN to support the network-based customer VPN based on the routing configuration;

receiving a custom routing profile for the network-based customer VPN, the custom routing profile identifying one or more routing protocols to be used for one or more segments of the network-based customer VPN; and

automatically reconfiguring the network-based customer VPN by programmatically generating appropriate routing configurations for the plurality of VRs based on the routing information and the custom routing profile.

2. The method of claim **1**, wherein the custom routing profile is based upon the global customer routing profile.

3. The method of claim **1**, wherein said disseminating a subset of the routing information comprises reading subnets for sites of the plurality of custom sites and creating static routes for the subnets.

4. The method of claim **1**, wherein said disseminating a subset of the routing information comprises placing site reachability information in one or more directories and providing access to the one or more directories via Lightweight Directory Access Protocol (LDAP).

5. The method of claim **1**, wherein said disseminating a subset of the routing information use of a static configuration in which the subnets are manually configured into a plurality of network-based customer VPNs.

6. The method of claim **1**, wherein said disseminating a subset of the routing information comprises exchanging the subset of the routing information via one or more routing protocols.

7. The method of claim **1**, wherein said disseminating a subset of the routing information comprises conveying the subset of the routing information via Multiprotocol Label Switching Label Distribution Protocol (MPLS LDP).

8. The method of claim **1**, wherein the custom routing profile comprises an Open Shortest Path First (OSPF) profile and wherein the OSPF profile includes a route aggregation policy.

9. The method of claim **1**, wherein the custom routing profile includes parameters relating to one or more of Internet Protocol Security (IPSec), LT2P, Point-to-Point Tunneling Protocol (PPTP), Generic Route Encapsulation (GRE) protocol and Multiprotocol Label Switching (MPLS).

10. A non-transitory program storage device readable by one or more computer systems of a service provider, tangibly embodying a program of instructions executable by one or more computer processors of the one or more computer systems to perform a method comprising:

disseminating a subset of the routing information among routers associated with a plurality of network-based customer VPNs for a plurality of customers;

generating a routing configuration for a network-based customer VPN of the plurality of network-based customer VPNs based on the routing information and a global customer routing profile of the network-based customer;

provisioning a plurality of virtual routers (VRs) distributed among the plurality of service processing switches and partitioned to the network-based customer VPN to support the network-based customer VPN based on the routing configuration;

receiving a custom routing profile for the network-based customer VPN, the custom routing profile identifying one or more routing protocols to be used for one or more segments of the network-based customer VPN; and

automatically reconfiguring the network-based customer VPN by programmatically generating appropriate routing configurations for the plurality of VRs based on the routing information and the custom routing profile.

11. The program storage device of claim **10**, wherein the custom routing profile is based upon the global customer routing profile.

12. The program storage device of claim **10**, wherein said disseminating a subset of the routing information comprises reading subnets for sites of the plurality of custom sites and creating static routes for the subnets.

13. The program storage device of claim **10**, wherein said disseminating a subset of the routing information comprises placing site reachability information in one or more directories and providing access to the one or more directories via Lightweight Directory Access Protocol (LDAP).

14. The program storage device of claim **10**, wherein said disseminating a subset of the routing information use of a static configuration in which the subnets are manually configured into a plurality of network-based customer VPNs.

15. The program storage device of claim **10**, wherein said disseminating a subset of the routing information comprises exchanging the subset of the routing information via one or more routing protocols.

16. The program storage device of claim **10**, wherein said disseminating a subset of the routing information comprises conveying the subset of the routing information via Multiprotocol Label Switching Label Distribution Protocol (MPLS LDP).

17. The program storage device of claim **10**, wherein the custom routing profile comprises an Open Shortest Path First (OSPF) profile and wherein the OSPF profile includes a route aggregation policy.

18. The program storage device of claim **10**, wherein the custom routing profile includes parameters relating to one or more of Internet Protocol Security (IPSec), LT2P, Point-to-Point Tunneling Protocol (PPTP), Generic Route Encapsulation (GRE) protocol and Multiprotocol Label Switching (MPLS).

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