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MASTER THESIS

TITLE: Design and operating plan for a communications infrastructure able to offer ISP and Datacenter services.

MASTER DEGREE: Master in Science in Telecommunication Engineering & Management

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DATE: 11-12-09

Resumen

Este proyecto es fruto de una beca en el departamento de redes en uno de los principales Gold Partner de Cisco en España. Dicho convenio, comenzó a finales del verano del 2008, una vez asentado en la empresa empecé a observar y captar experiencia en lo relativo a la estructura, organización, funcionamiento y actividad de la empresa y su entorno. Observando el tipo de mercado y el comportamiento de los clientes, vi que la situación de crisis actual daba como resultado que empresas redujeran sus presupuestos en TI y que muchas de las que se podían sumar en la inversión en las tecnologías de la información finalmente aplazaban sus proyectos por no disponer de capital. A la vez, exigían mejores resultados de sus inversiones, solicitando servicios con mayor nivel tecnológico, SLA's (*Service Level Agreement*) más elevados y un soporte postventa más eficiente.

Lo comentado anteriormente me motivó en el estudio en profundidad del funcionamiento de la empresa y sus procedimientos para poder mejorarlos y poder introducir un nuevo modelo a la hora de ofrecer servicios tecnológicos que cumpla las necesidades actuales de la sociedad. Todo ello me hizo pensar la posibilidad de desarrollar este proyecto, el cual se basa en introducir un nuevo modelo de externalización mediante las últimas tecnologías que podemos encontrar en el mercado.

Este proyecto analiza diferentes tecnologías referentes a comunicaciones WAN y Datacenter con el objetivo de crear un nuevo modelo de exportación de servicios y activos TI, basado en un único proveedor de servicios de comunicaciones. Este modelo se basa en la de exportación de servicios y activos TI de las empresas en una infraestructura facilitada por un proveedor, la cual se basaría en un Datacenter. Este modelo permitiría unificar las necesidades TI de las empresas de forma ágil, flexible y económica con un único proveedor de servicios a la vez de poder despreocuparse de todo el tema tecnológico y poderse centrar en sus negocios.

Una vez introducida la infraestructura necesaria para albergar los servicios y activos IT de los clientes, se mostrará un diseño de un posible plan de explotación del nuevo modelo, indicando los procesos que intervienen. Posteriormente, se introducen los principales beneficios empresariales que aporta el nuevo modelo y finalmente mostraremos un ejemplo de implantación del nuevo modelo de servicios externalizados en varios cliente tipo.

Es importante tener en cuenta que aún no existe ningún otro proveedor de comunicaciones en España con las características propuestas en este proyecto, además, para conseguir el objetivo de este proyecto he tenido que estudiar en profundidad una amplia gama de tecnologías y protocolos. Entre ellos se destacan MP-BGP, MPLS/VPN, OSPF, Fiber Channel over Ethernet, software de virtualización, LAN y dispositivos de red WAN, los Datacenter y también la comprensión sobre el mundo del ISP y su funcionamiento.

Uno de los principales problemas que se han resuelto en este proyecto es el

uso de la tecnología MPLS/ VPN como medio para enviar información segura a través de una red WAN compartida de forma altamente escalable y rentable con la posibilidad de garantizar QoS (Quality of Service). Esto ha sido posible con el diseño *Carrier Supporting Carrier* (CsC) de MPLS / VPN.

Inicié el proyecto con un conocimiento muy limitado sobre estas tecnologías, pero una vez comprendida decidí poner en práctica una red MPLS/VPN CsC real utilizando un simulador de routers Cisco (GNS3), el cual nos demuestra que la solución propuesta en este proyecto es funcional.

Cabe destacar que durante el desarrollo de este proyecto conté con asesoramientos de diferentes ingenieros sénior e ingenieros con certificados CCIE’s (Cisco Certified Internetwork Expert).

Títulol: Design and operating plan for a communications infrastructure able to offer ISP and Datacenter services.

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Overview

This project arises as a result of a fellowship in a networking department of one of the main Spanish Cisco Gold Partners. The agreement started in late summer 2008, and once in the company I began to observe and get experience regarding the structure, organization, operation and activities of the company and its environment. Looking at the IT market and analyzing the customer's behaviour, I saw that IT budgets were being reduced due to the current crisis and that some of the companies with strong IT investments finally postponed their projects due to lack of capital. At the same time, companies require to optimize their returns on investment, requesting better services with higher technological level, higher SLA's (*Service Level Agreement*) and being more efficient with the after-sales support.

All of this motivated me in doing a deep study about how the fellowship company operates and which were their procedures just to try to improve them and to introduce a new model to provide technological services to meet the current needs of the society. This made me think about the possibility of developing this project, which is based on introducing a new model of outsourcing using the latest technologies that can currently be found at the market.

The project analyzes different technologies and WAN communications concerning Datacenter with the goal of creating a new model to export services and IT assets, based on a single communications provider for LAN and WAN services. This model is based on the export of IT services and assets from companies with infrastructure provided by a single vendor, which would be based on a Datacenter. This model would unify the enterprise IT needs in an agile, flexible and cost effective way with a single service provider while being able to ignore all the technological issues and focus on their business.

Having introduced the necessary infrastructure to house IT services and customer assets, I will show a possible design of a business plan of the new model, indicating the processes involved. Subsequently entered the business benefits brought by the new model and finally show an example of introducing

the new model of outsourced services in several customer types.

It is important to note that there is still no other communications provider in Spain with the characteristics proposed in this project, therefore, to meet the objective of the project I have had to study in depth a wide range of technologies and protocols. Among them we highlight MP-BGP, MPLS/VPN, OSPF, Fiber Channel over Ethernet technology, virtualization software, LAN and WAN networking devices, Datacenter devices and also an understanding about the ISP world and its operation.

One of the main problems that have been resolved in this project is to be able of sending information securely over a shared WAN network in a highly scalable and cost effective way with the possibility of ensuring QoS (*Quality of Service*). This has been possible with the use of MPLS/VPN *Carrier Supporting Carrier* (CsC) model. I had limited knowledge of the operation of this technology but once I realized that it was the best solution, I decided to implement a real MPLS/VPN CsC network using a Cisco router simulator that showed me that the solution proposed in this project was functional.

It is noteworthy that during the development of this project I was advised by various senior engineers and CCIEs (Cisco Certified Internetwork Expert).

Querría agradecer a todas aquellas personas que me han apoyado durante la realización de este proyecto: mis compañeros de Unitronics, mi supervisor Sebastià Sallent, quien siempre me ha ayudado a enfocar académicamente el proyecto. Estela, por darme su apoyo durante todo el proceso.
Y muy especialmente, a mi tutor Òscar Caparrós, quien siempre me ha dado soporte cuando lo he necesitado.

CONTENTS

CHAPTER 1. INTRODUCTION

Nowadays, information technology (IT) is increasing its importance role at the business. Companies, of all type and dimensions are growing the demand and invest with the objective of growing competitiveness in the market, trying to reduce costs and simplify management of their technology.

In this difficult economic scenario, the behaviour of the macro-IT in Spain during 2009 is moderately positive but uneven, though. It was confirmed as a sector more resilient than others in the economic crisis. This situation should not lead to mislead, the sector has not been immune to the effect of the crisis, most notably the worsening situation in the last quarter of 2008, which have led to various macro-IT markets to have not a uniform behaviour. According to the multinational association of Spanish companies (*asimelec*) [1], the number of macro-global IT market amounted in 2008 to 77,431.5 million Euros, which was a stalemate over the same period of 2007.

In the current context, all analysts agree on the need to seek a change in the Spanish production model that encourages activities that provide added value. The impetus to R & D appears as the key to impulse productivity and competitiveness of all productive sectors. But the impetus to R & D alone will not suffice, if not accompanied by a significant investment in technology, a clear commitment to the IT sector, and a collective effort by the diffusion of technologies information and communications in all productive sectors of the economy.

The situation discussed previously justify the goal of this project, which is based on the search for a new model of supplying services, which provide a solution to the IT needs of enterprises, reducing cost, simplifying and unifying management services by introducing a new model of outsourcing. This new model should has the following characteristics:

- Unify a wide range of technology services in a single product, providing a bigger services portfolio to the customers.
- Minimize the initial economic impact at the time of the introduction of an IT service, reducing the installation process and the cost of the implantation of the new hardware.
- Minimize the cost of maintenance and equipment management.
- Reduce the qualified technical personnel in client.

1.1 Goal of the project

The goal of this project is to search and analyze different technologies demonstrating the technological and business viability of a new model to export IT. This new model is based on the export of technologies assets of the business in an infrastructure provided by the provider. This model would allow unifying the enterprise's IT needs in easy way, flexible and economic with a single services provider. For this purpose, was performed a study of the current state of technology. Finally design and simulate by software GNS3 the a real scenario of the WAN solution proposed, to demonstrate that the technology and solution proposed in the project is functional.

Later we will discuse he business benefits provided by the new model, design a business plan (showing the processes involved), and finally will show an example of introducing the new service on a client type.

We can see in the figures *fig. 1.1* and *fig. 1.2*, the summary of the objective of this project, showing how IT services are currently offered to companies, and how they are able to be offered with the idea that I propose.

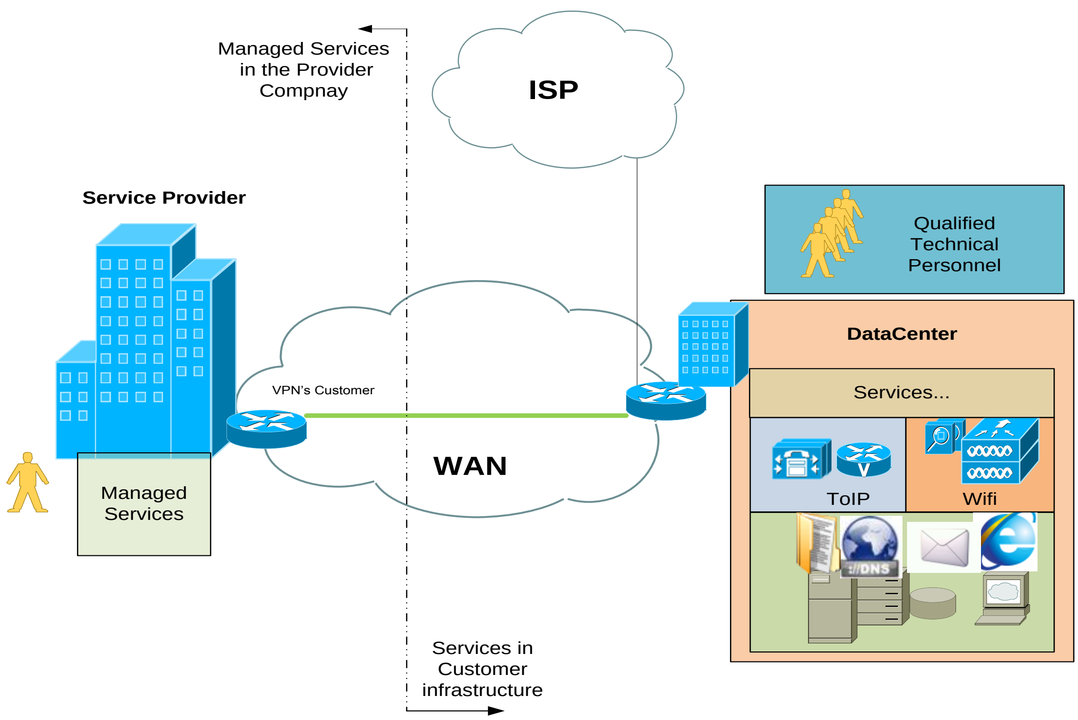


Fig. 1.1 Customer Services managed by Provider Company

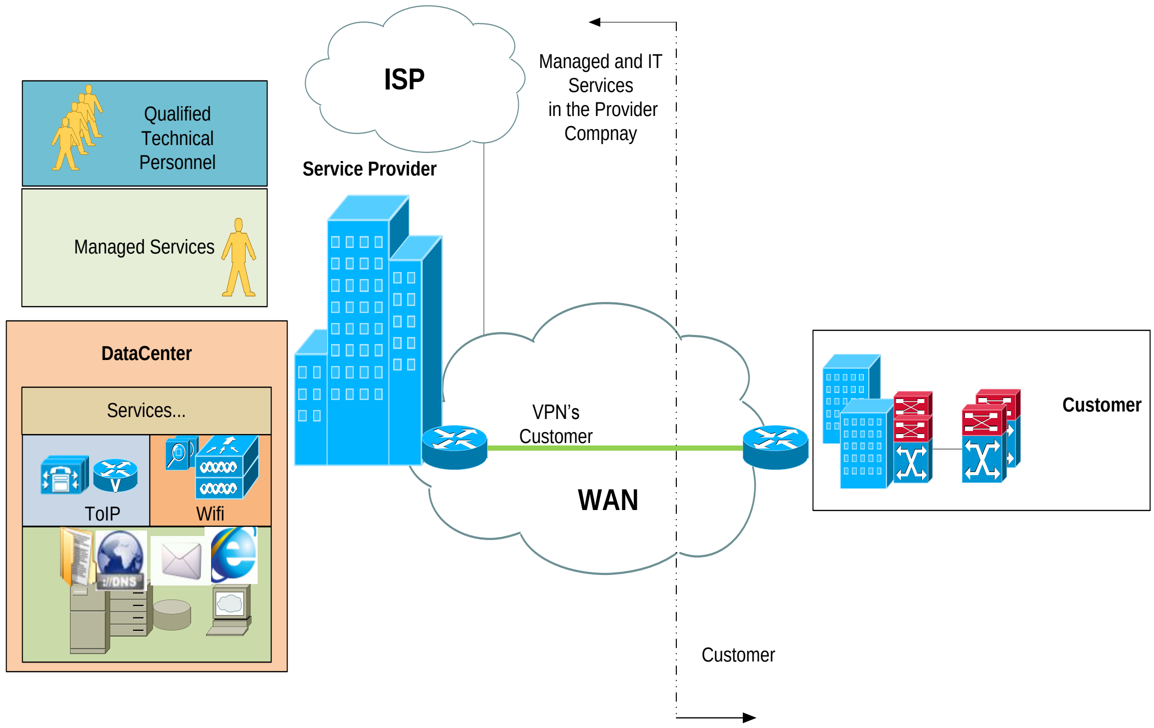


Fig 1.2 Company shared their infrastructure with Customers with a minimum TI infrastructure over WAN connection.

1.2 Motivation of the thesis

The project is carried out as part of a fellowship. The fellowship agreement, began in late summer 2008 at the Networking Projects Department. The first phase of the agreement was based on an intense period of job training supervised by Òscar Caparrós (director of this project), which helped me acquire knowledge of our suppliers and company procedures.

After this first phase, I began to involve in several projects of the company, from the initial design study up to the final implementation, even being responsible for several parts of its phases.

Once settled in the company, I began to observe and to get experience about the structure, organization, working and activity of the company. Observing the market rate and the behaviour of customers, I saw that the current crisis implied the different companies to reduce their IT budgets. Many of them (which could invest in Information Technology), finally postponed their projects due to lack of capital, at the same time, demand to improve their benefices and results of their investment, requesting services with higher technological level, higher SLA's (*Service Level Agreement*) and more efficient after-sales support.

All this will motivated me to study in depth the different jobs of the company and theirs procedures, just to try to improve them introducing a new model in providing technological services to meet the current needs of society.

1.3 The Company

The company is a leading group in the implementation, migration and Network connectivity in Spain, and the officially-approved partner of the top manufacturers.

It has more than 40 years of experience in the IT Communications sector and more than 240 university graduates in 9 centres, receiving the confidence of 82 of the top 100 Spanish companies. We can see in the Figure *fig. 1.3* their main certifications:

Fig.1.3 Main Certifications

The company considers technology a tool to give value at the business, employees, customers and suppliers. Their list of services covers the needs at the different levels from the following:

- Consulting and Solutions.
- Design and Implementation
- Management services

It is interesting to know the way that this company has into account the risks of this technological market...it has a wide range of types of IT services and customers (deals fairly with both, private and public sectors) and tries to be partner of the main manufacturers.

CHAPTER 2. COMMUNICATIONS INFRAESTRUCTURE DESIGN

As I mentioned previously, one of the objectives of this project is to develop a business model of outsourcing. To achieve that, I need first to search different technologies that show us the feasibility of a communications and information infrastructure located in the distributor company also called *Datacenter[2]*.

In this chapter I going to expose the features needed to allow this business model and after that I will describe each one of the parties technologies needed to fulfil the features that will make possible the new externalization model of services. I will also talk about the “why” of each decision. At the end, I will expose the final solution with showing all the technology.

Datacenter is a facility used to house computer systems and associated components, such as telecommunications and storage systems. It usually includes redundant or backup power supplies, redundant data communications connections and security devices, like you can see in the figure *fig. 2.1*. This network architecture gives operational simplicity, agility, and greater efficiency to IT services. It accelerates applications and service deployments, enabling greater productivity with less cost and complexity.

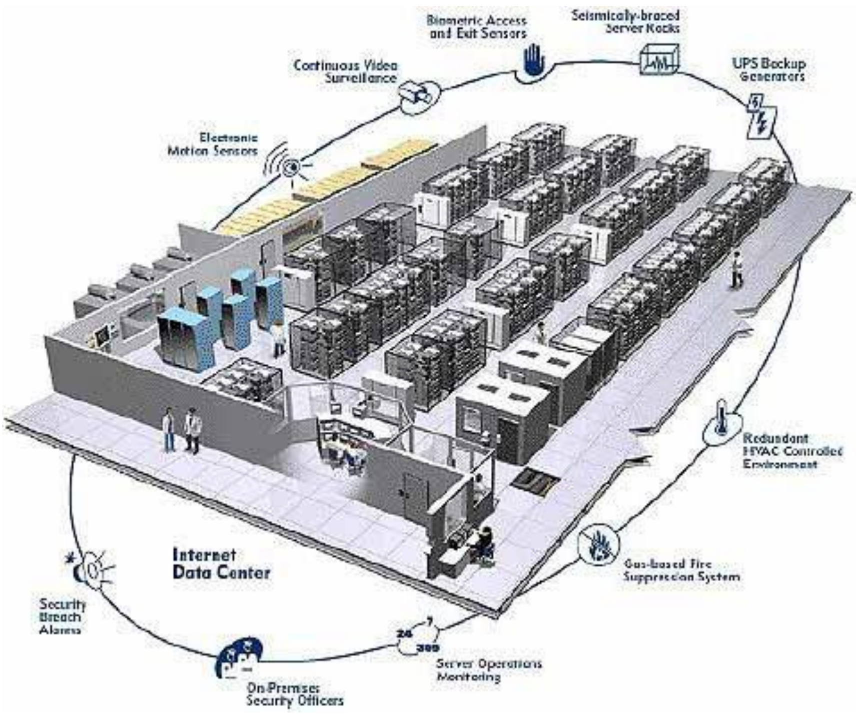


Fig. 2.1 *Datacenter* by XpressHost™

In our solution we must to have an infrastructure that allow us simplify the IT structures of many different customers. We have to take into account many features, among which we have to stress the following aspects:

- **Unified Fabric**: Simplify server connectivity, cabling, Datacenter infrastructure, administration, and management.
- **Unified Computing**: integrate network, compute and virtualization resources into a cohesive system.

2.1 Unified Fabric

It is so important to indicate that there are a lot of servers hosted in *Datacenters* distributed over store area networks (SAN). Today, all major SAN equipment vendors also offer some form of *Fibre Channel* (FC) routing solution. *Fibre Channel* is standardized in RFC 3643[3].

FC is a serial data transfer interface that it is currently used to link around speeds of 1 Gigabit per second (1 Gbps). FC allows to interconnect features of the networks (networking) and I/O High-Speed (mass storage mainly) under a single technology. FC have made possible the development of a new way to implement disk or tapes (that are no longer physically associated with a specific server) and it can be separated at some distance even.

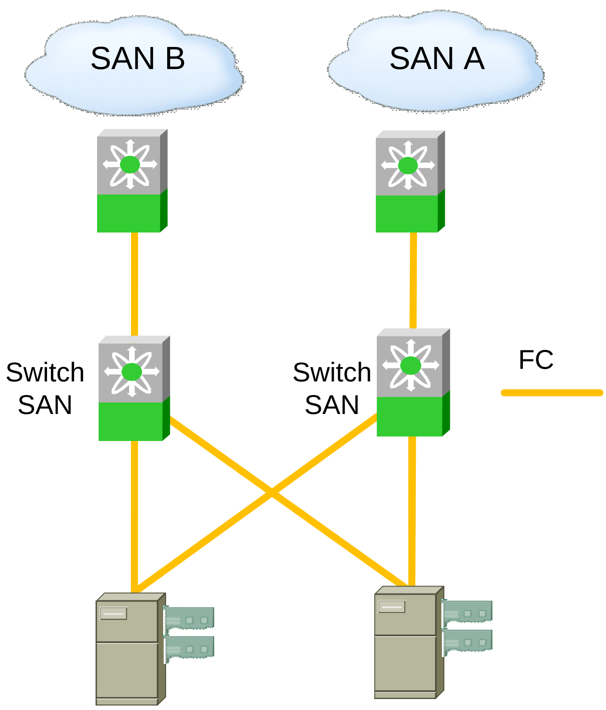


Fig. 2.2 Fibre Channel Network

The typical *Datacenter* environment supports two to three parallel networks: one for data, one for storage. In addition, servers often have dedicated interfaces for management, backup, or virtual machine live migration. Supporting these interfaces imposes significant costs related to interfaces, cabling, rack space, upstream switches, and power and cooling.

2.1.1 Fiber Channel over Ethernet

During the design of the project I have observed the needed to found a solution that allows us to reduce the IT infrastructure of our *Datacenter*, because we have to take into a count that we will have a big number of customers, for this we need a way to reduce as possible the infrastructure while being scalable functional and robust.

Recently we are able to found the emerging standard FCoE, (Fiber *Channel* over Ethernet), on Wednesday June 3, 2009, the FC-BB-5 working group of T11 completed the development of the draft standard[4].

FCoE is a protocol to transfer data between physical and virtual servers with storage systems using the highly reliable protocol over high speed networks Ethernet of 10 Gbps. FCoE maps Fibre Channel natively over Ethernet while being independent of the Ethernet forwarding scheme. The *FCoE* protocol specification replaces the layers of the *Fibre Channel* stack with Ethernet. By retaining the native *Fibre Channel* build, FCoE allows a seamless integration with existing *Fibre Channel* networks and management software.

In the figure 2.3 we can see like the FC information is encapsulated in the Ethernet frame.

Fig. 2.3 Encapsulated package using *FCoE*

FCoE consolidates these different types of traffic onto a single, general-purpose, high-performance, highly available network that greatly simplifies the network infrastructure and reduces costs (see figure *fig.2.4*).

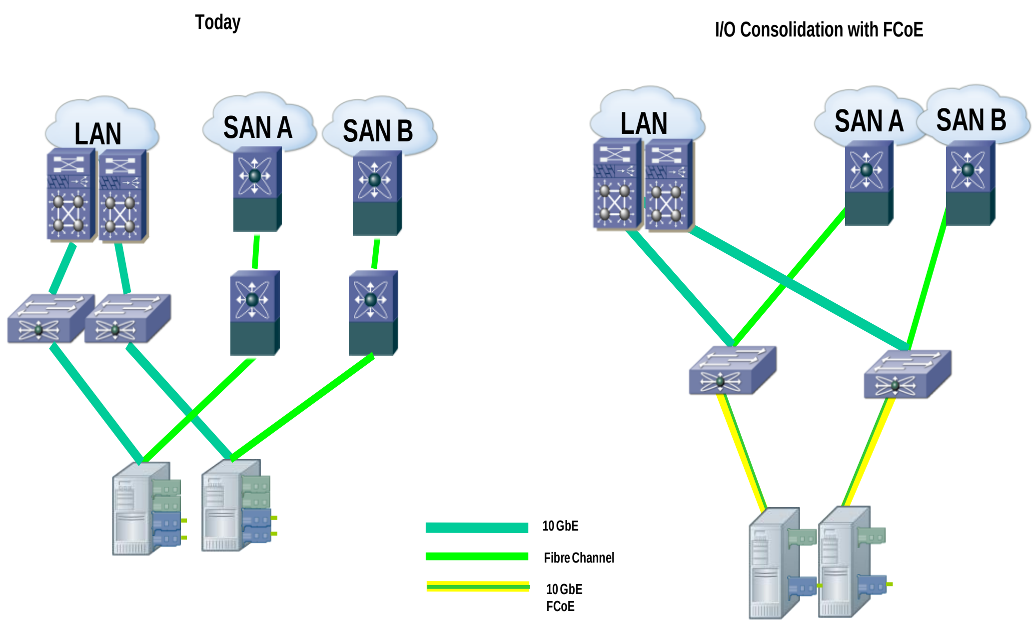


Fig. 2.4 *Fiber Channel* over Ethernet

It is worth noting that a server, or storage unit, is connected in parallel to the LAN and SAN. Therefore it is necessary to have the hardware required for each feature. Typical server in *Datacenters* have five up to seven I/O interfaces. A unified I/O adaptor that adequately supports the unique and varied traffic requirements of *Datacenter* applications can reduce the number of network devices, server-network interfaces, and cables used to interconnect them. Unified I/O can also lead to a major reduction in *Datacenter* power requirements; power is the most limited resource available to *Datacenter* managers today. With *FCoE* technology, servers, instead of having multiple discrete I/O adaptors for LAN and SAN traffic, will have a smaller number of *converged network adapters* (CNAs)[5] that support both LAN and *Fibre Channel* SAN traffic.

In the fig.2.5 we can see the hardware reduction needed enabled by CNA cards.

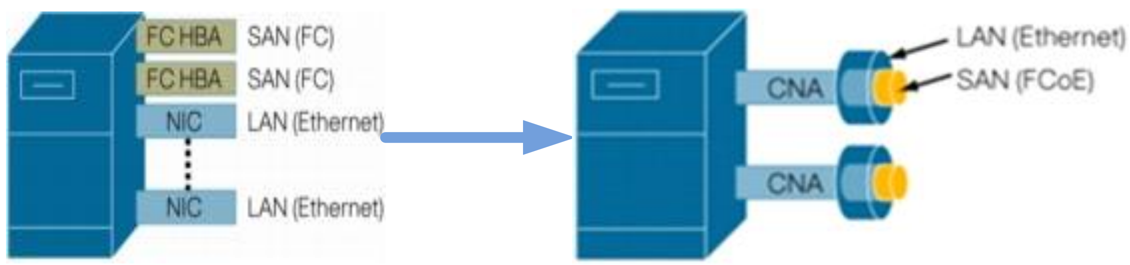


Fig. 2.5 FiberChannel over Ethernet over CNAs

In Figure *fig. 2.6* we see an example of the use of bandwidth of a server connected independently in the LAN and SAN to another server that unifies all communications over *FCoE*.

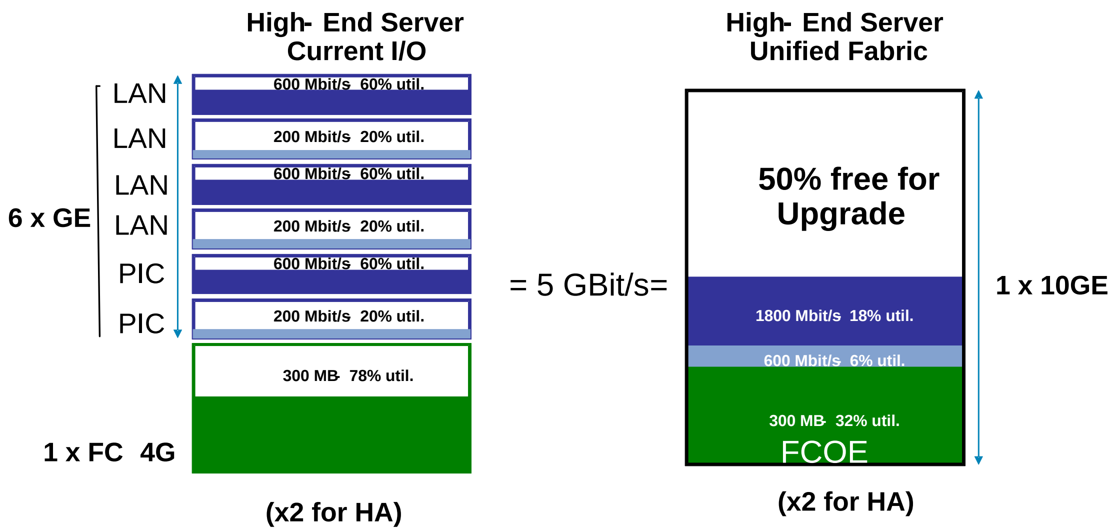


Fig. 2.6 Performance improvement in bandwidth by *FCoE*

2.2 Unified Computing

We have to take into account that the company will has a lot of IT services hosted in their *Datacenter*. The cost-effective utilization of IT infrastructure, responsiveness in supporting new business initiatives and flexibility in adapting to organizational changes will must to be the principal goals of the supply company. Driving an additional sense of urgency is the continued climate of IT budget constraints and more stringent regulatory requirements. In order of this, it is important to found a way to host all services more effectively and scalability. Nowadays, we can found different technologies, in which can offer us diverse ways to unify different S.O in the same hardware.

Virtualization is a fundamental technological innovation that allows skilled IT managers to deploy creative solutions to such business.

The term virtualization broadly describes the separation of a resource or request for a service from the underlying physical delivery of that service. Virtualization provides a layer of abstraction between computing, storage and networking hardware, and the applications running on it (see figure 2.7). The deployment of virtual infrastructure is non-disruptive, since the user experiences are largely unchanged. However, virtual infrastructure gives administrators the advantage of managing pooled resources across the enterprise, allowing IT managers to be more responsive to dynamic organizational needs and to better leverage infrastructure investments.

Before virtualization we found single OS (Operating System) image per machine and running multiple applications OS same machine often creates conflict. Moreover, we underutilized resources, in this way we have an Inflexible and costly infrastructure.
In short, these will be the principal benefits of the virtualization:

- Hardware-independence of operating system applications
- Virtual machines can be provisioned to any system.
- Can manage OS and application as single unit by encapsulating them into virtual machines.

In this way we can place a lot of virtualized services in the same hardware.

In figure *2.7* we can see an example of the benefits of virtualization applied in this project.

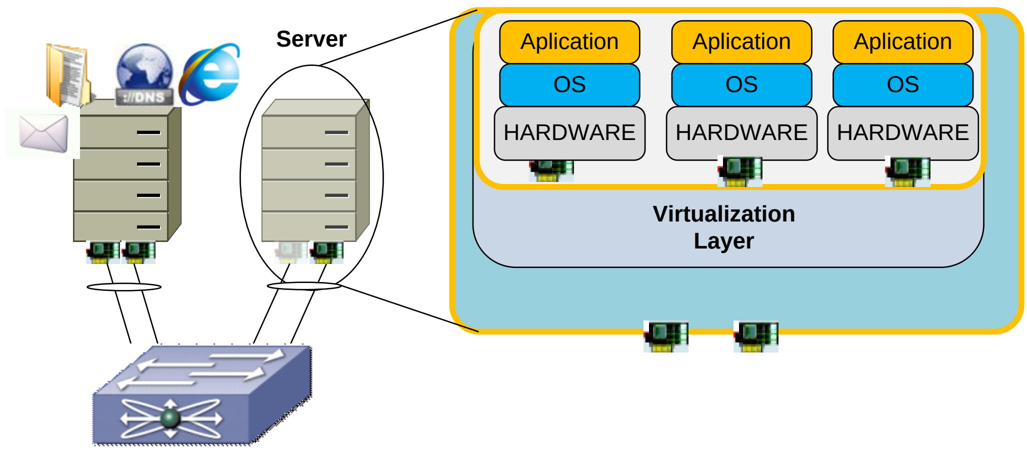


Fig. 2.7 Operating System (OS) virtualized in server.

2.3 *Datacenter* Network Topology

We will use a modular scheme for network designing. It is based on an architecture that allows the expansion and provides network scalability. Most logical architectures for routing and switching are based around a system whereby three sets of functions are abstracted logically from one another. A common one is *Core*, *Distribution* and *Access*.

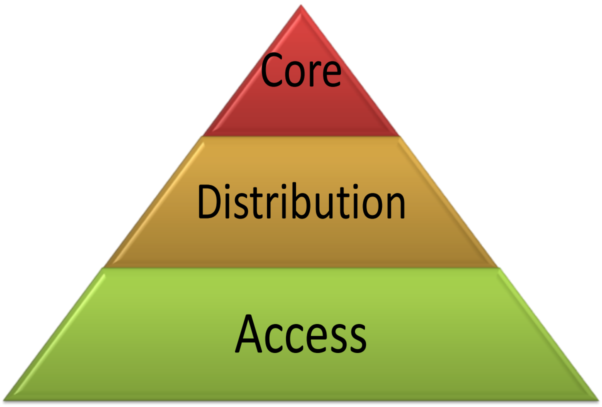


Fig. 2.8 Modular scheme for network designing.

2.3.1 Access layer

The **access layer** is present where the end hosts are connected to the network. Devices in this layer, sometimes called building access switches, should have the following capabilities:

- Low cost per switch port
- High port density
- Scalable uplinks to higher layers
- User access functions such as VLAN membership, traffic and protocol filtering, and QoS
- Resiliency through multiple uplinks

Our *Datacenter* has specific server networking needs and it is based in the *unified fabric Ethernet-FC*, that's designed to meet those needs.

- High-performance 10 Gigabit Ethernet
- *Fibre Channel* over Ethernet (*FCoE*)
- Virtual-machine-optimized networking

2.3.2 Distribution

The distribution layer provides interconnection between the *access* and *core* layers. Devices in this layer, sometimes called building distribution switches, should have the following capabilities:

- High Layer 3 throughput for packet handling
- Security and policy-based connectivity functions through access lists or packet filters
- QoS features
- Scalable and resilient high-speed links to the core and access layers

2.3.3 Core

Core layer provides connectivity of all distribution layer devices. The *core*, Sometimes referred to as the backbone, must be capable of switching traffic as efficiently as possible. *Core* devices should have the following attributes:

- Very high throughput at Layer 2 or Layer 3
- No costly or unnecessary packet manipulations (access lists, packet filtering)
- Redundancy and resilience for high availability
- Advanced QoS functions

In the core we will need a Modular Switch[6], because offers a wide range of integrated service modules on a single networking platform. These service modules add Layer 4-7 functionality to the existing Layer 2-3 capabilities of the switch, transforming the core into a fully functional Layer 2-7 device. The integrated service modules use the high-speed switching backplane and intelligent networking capabilities to:

- Optimize capacity and bandwidth to manage multiple advanced bandwidth-intensive applications without service degradation
- Protect the network against threats at all levels.

The strong need for information security, the availability of sensitive information stored in corporations and governments databases to the outside world is attributed to numerous factors. The ease with which that malicious code can be distributed by people via automation over Internet, makes to take into account specific hardware within core to solve this problem.

A firewall is a member of hardware (a router) usually placed between the Internet (*Untrust Network*) and database servers of internal network. Any guess to the database has to go through the firewall before it is either denied or granted access. It attempts to guarantee that only authorized clients can access the server.

In Figure fig. *2.9*', we can see a physical representation of the modules and chassis of the *Modular Switching* of Cisco.

Modular Wireless Controller

Modular Firewall

Modular Switching Chassis

Fig. 2.9 Modules and chassis of the Modular Switching of Cisco (Catalyst 6500).

2.3.4 Router Edge

The Router Edge is the front end with the *Backbone carrier*, it will be responsible for carrying out the connection WAN between our core and the provider. Their principals features are high availability and processing capacity.

2.3.5 Logical Networking Topology

In the figure *fig. 2.10* we are going to show schematically the logical and access layer of the main elements of the *Datacenter*'s network.

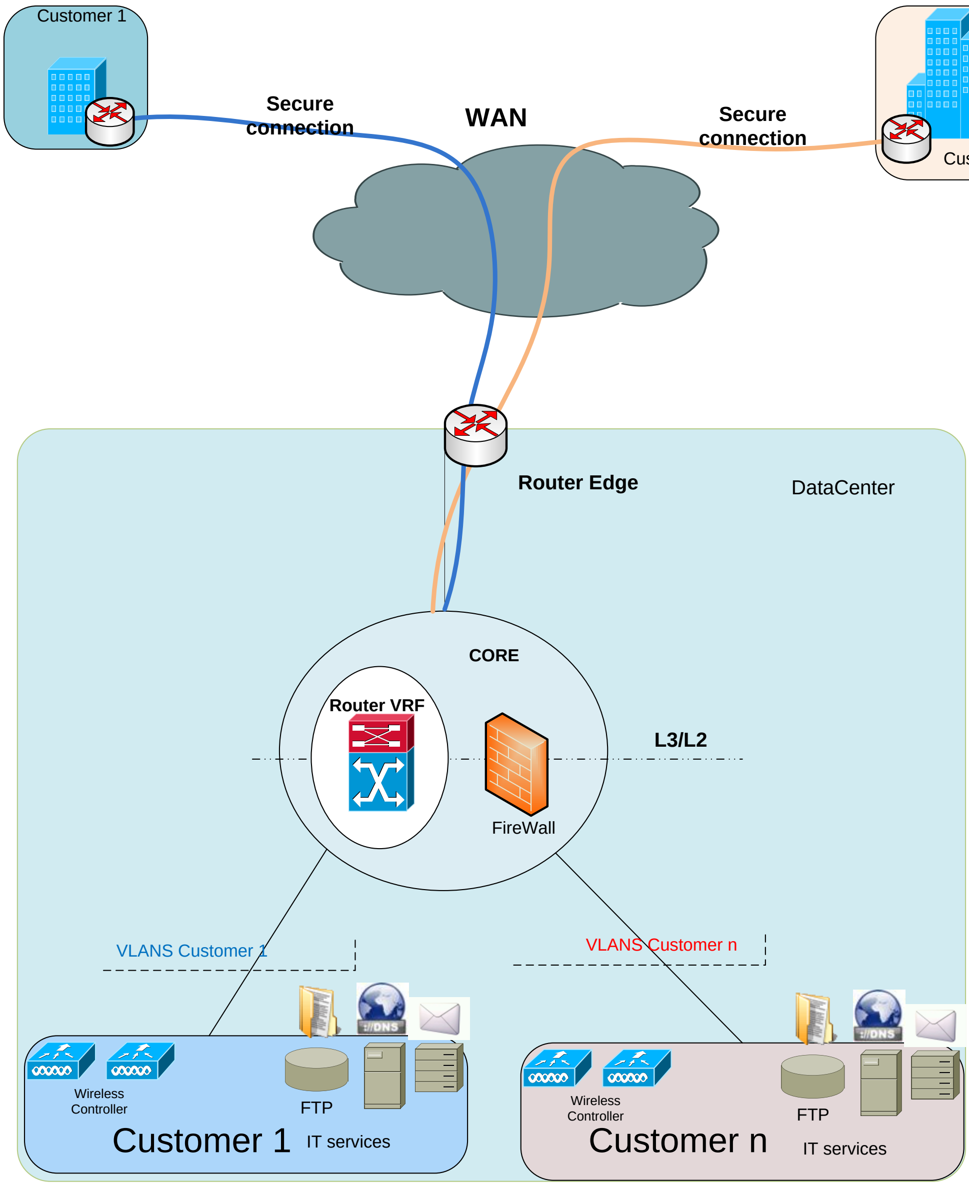


Fig. 2.10 Logical and access layer of the main elements of the Datacenter's network

2.3.6 Physical Networking Topology

In Figure *fig. 2.*11, we can see a physical representation of the most important elements of physical networking. Also, we can see the distribution by network levels and the redundancy of connection between them.

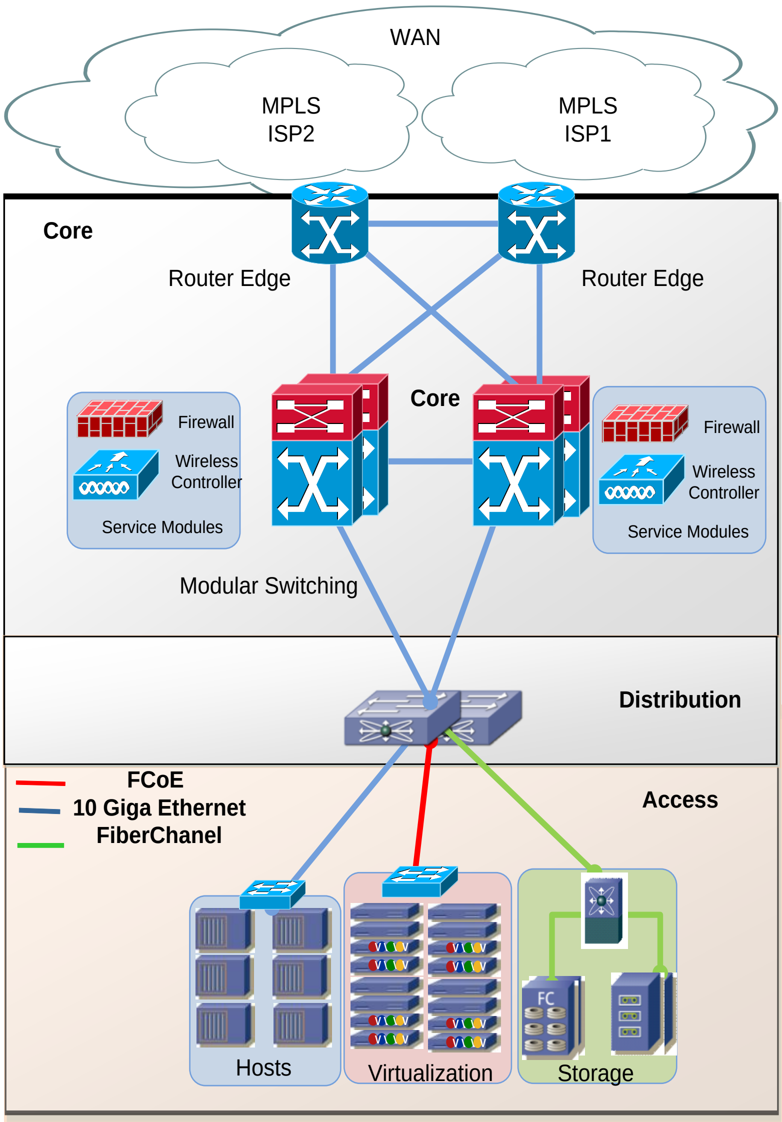


Fig. 2.11 Physical representation of the most important elements of the *Datacenter* Networking

2.4 Services

In this point we are going to show the main services that the *Datacenter* could offer, which will be the outsourced services that don't need an initial expensive inversion. The services offered will be the next:

- Hosting (Server, WEB/FTP/mail)
- Advanced services of Wireless.
- ToIP
- Security (Firewall Services Module)
- Load Balancing
- ISP services

It is important to stress that the services of wireless, security and Load Balancing could be implemented in *Datacenter* using a *Modular Switching Core*.

2.4.1 Hosting

To enable the client to concentrate on its core business and to reduce the infrastructure and resources that your company spends to host your website, corporate email, or their most critical and complex applications, the service company could host on their virtualized serves in the *Datacenter*, while, at the same time, we offer *Managed Services Data* and emphasize that we would offer maximum reliability and security, having the best connectivity at network Internet.

Note that due to virtualization we could give hosting services to multiple clients through a single server.

When accommodate various virtualized server in the same hardware, we need to get high powered, fully scalable availability hardware in *Datacenter* scenarios. *Blade servers* are stripped down computer servers with a modular design optimized to minimize the use of physical space. Whereas a standard rack-mount server can work with (at least) a power cord and network cable, blade servers have many components removed to save space, minimize power consumption and other considerations, while still having all the functional components to be considered a computer.

2.4.2 Advanced services of Wireless.

The emergence of simple 802.11[7] AP (*Access Points*) that are managed by a WLAN appliance suggests that having a standardized, interoperable protocol could radically simplify the deployment and management of wireless networks. The general goal has been to move most of the traditional wireless functionality such as access control, mobility and radio management out of the access point into a centralized controller.

The IETF's CAPWAP WG has identified (March 2007) that a standards based protocol is necessary between a wireless Access Controller and Wireless Termination, also called Access Points. This specification defines the *Light Weight Access Point Protocol* (LWAPP)[8].

The Wireless services, that *Datacenter* offer, would be designed to provide wireless solutions based on Standard 802.11. This would consist of *Wireless Services Modules* of the *Modular Switching* or hardware specific. In which radio management out of the access point into a centralized controller. The access points 'light' (Lightweight APs-Lapse) are managed and controlled via the LWAPP protocol, which conducts a secure communication tunnel between *Wireless Services Modules* and *Access Points* (AP). The operating system of the Wireless module, manages all customer information, communications and system management functions, improve wireless resource management and manages a broad spectrum of mobility policies, coordinating all security functions.

A third component is the software platform for management of 802.11n and 802.11a/b/g enterprise-class wireless networks, also known as Wireless Control System (WCS)[9]. This component allows planning, monitoring, troubleshooting and reporting on indoor and outdoor wireless networks. The software is able to analyze the wireless performance and enhance it. Note that the software could be virtualized on a server, so it is able to provide advanced wireless services to a multitude of companies simultaneously.

The proposed solution would be as shown in Figure *fig. 2.12*, where we can see (on the left) the wireless solution, and on the right, how would be outsourced in a *Datacenter*.

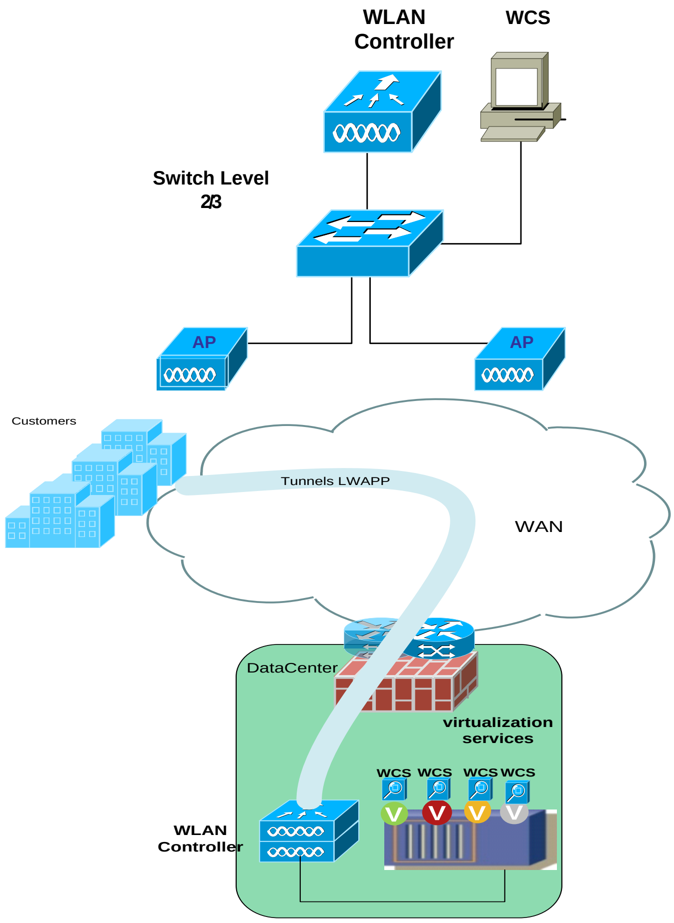


Fig. 2.12 The wireless solution (the left), and on the right, how would be outsourced in a *Datacenter*.

2.4.3 ToIP

Telephony over IP (ToIP) is a set of resources that enable voice signal travelling through the network using IP protocol. ToIP is used to send packets of voice using a signalling protocol (SIP/H.225/H.245)for the establishment and control end the call. Also, it counts with transport protocol to send data (UDP / RTP / RTCP).

The structure of any system designed to provide ToIP services to a large number of users contains of the following components:

- **Terminal**: software or hardware, which allows communication using an IP network either through local area network (LAN) or over the Internet. The IP phone converts and compresses the voice signal into data packets that are sent over the IP network.
- **VoIP proxy**: .It is software used to manage all aspects of IP telephony: telephones, gateways, etc. As a signalling system can use the following protocols such as H323, SIP, MGCP, SCCP (Cisco proprietary).
- **Router/Gateway**: routing and translating the voice packets to analogue network (PSTN), translate signalling protocols, or routing to a WAN connection.

Note that the Proxy VoIP software can be installed in a virtual server. Therefore, the scalability in providing this service is high, since with a single physical server we can create a VoIP proxy farm and thus supplying a large number of customers.

The proposed solution would be as shown in figure *2.13*, where you can see (on the left) the ToIP solution, and on the right how it would be outsourced in a *Datacenter*.

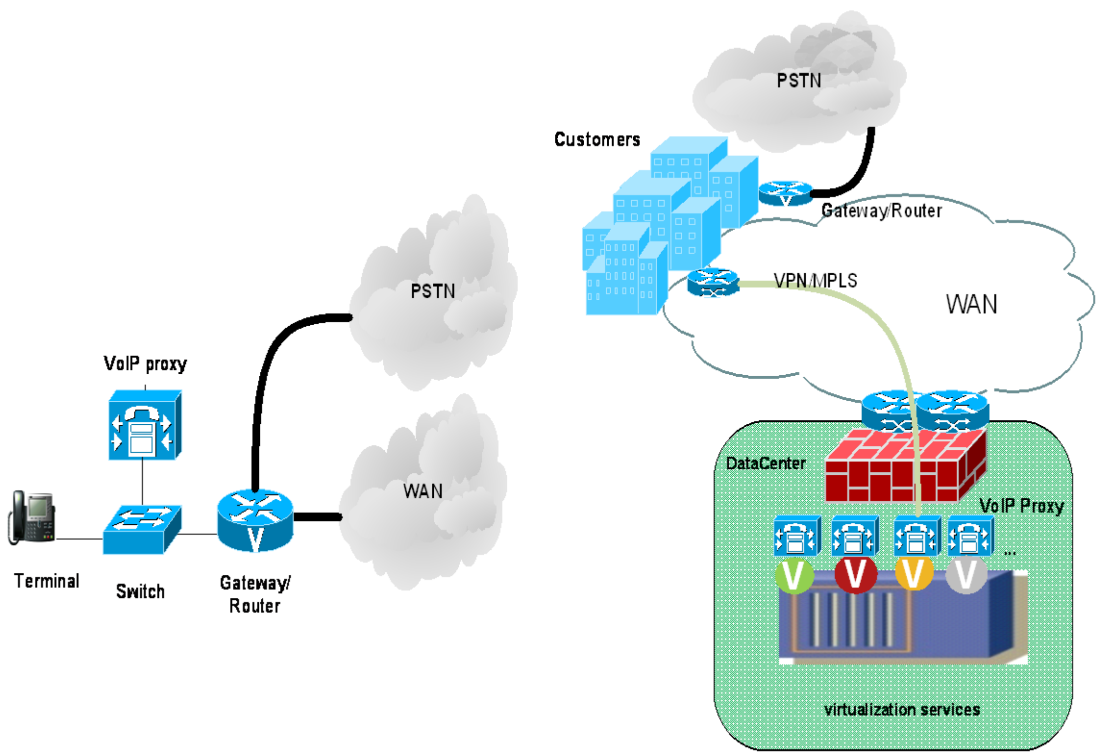


Fig. 2.13 Standard ToIP solution (on the left), and on the right, how would be outsourced in a *Datacenter*.

2.4.4 Firewall Services Module

Integrates high-performance stateful-inspection firewall with application and protocol-inspection engines into the network infrastructure, allowing any port to operate as a firewall port to prevent unauthorized access from outside users, and controlling which outside resources can be accessed by internal users.

Most Firewall in the market delivers strong application-layer security through intelligent, application-aware inspection engines that examine network flows at Layers 4 to 7, supplying market-leading protection to VoIP, multimedia, instant messaging, and peer-to-peer applications. Also, it enforces communication policies between VLANs and private VLANs and external interfaces, is important noting that the most Firewall delivers multiple virtual firewalls on one physical hardware platform, allowing service providers and large enterprises to implement policies for different customers or functional areas over the same physical infrastructure.

2.4.5 ISP Services

The fact of looking for the possibility of being able to offer a global IT solution make me think in becoming an ISP. Then, it would be a good way to give a plenary services portfolio to the company.

To provide ISP services through another ISP, we have different possibilities (depending on the kind of requirements of the customers) between them:

- Request to our contracted ISP as many public IP as customers we have.(Fixed IP)
- Share our group public IP between different customers. (Dynamic IP)

We only need how to offer these services between WAN connections. This one is explained in the CHAPTER 3.

The proposed solution would be as shown in figure *fig. 2.1*4

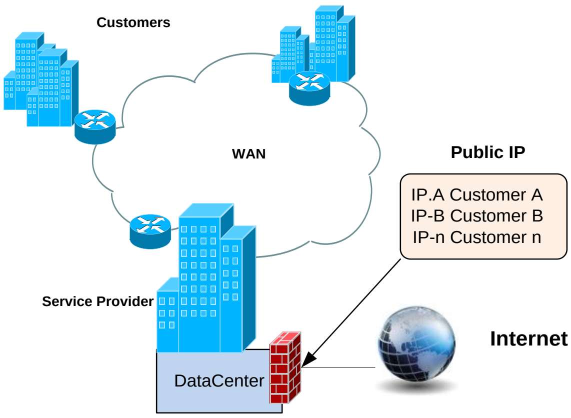


Fig. 2.14 A Shared IP public pool between customers

CHAPTER 3. CONNECTION BETWEEN SITES

As we said previously, the goal of the project is based on the export of technologies assets of the business in an infrastructure provided by the services supplier. In order to do this, one of our main searches will be to found a technology, in which it can accommodate the customer's IT infrastructure and, so, enabling high speed switching, unifying the services while providing security and high availability.

We have to assume that there's no special interest in the idea of doing a huge IT deployment to emerge as an independent ISP on the market, we mean, costs for achieving that are really high so finding an alternative will be the challenge. A good starting point will be to analyze the actual situation of the ISPs (what they are able to offer us) as well as knowing what will we require.

The first condition to offer services at the customer is to make a secure and reliable connection between the provider services through different data providers in large distances up to the customer.

How to give secure remote access at the customers in our TI infrastructure it is an important decision.

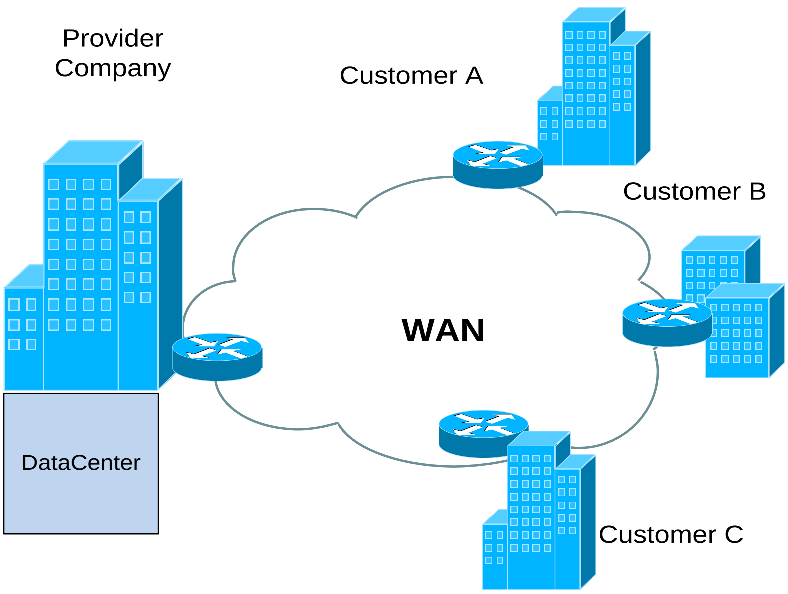


Fig. 3.1 Global vision of the Company and their customers.

It is worth noting that, for this project, the connections between the sites will be faster and transparent from the customer. The provider company will hire the Internet Services Provider services to make connections between our DataCenter and the customers.

An ISP is needed to make connections over long distances. An ISP is a company that offers at their customers, by their own network, access to the Internet. The ISP connects to its customers using a data transmission technology appropriate for delivering Internet Protocol datagram, such as dial-up, XDSL, cable modem, wireless or dedicated high-speed interconnects.

Before to make the connections between Service provider and customers, we have to take into account the features of the connection that we need.

Due to the types of services that the new model of services offers, is needed to make independent logical connections. In other words, between the customers and services, of the IT supplier, there cannot be logical visibility and routes and routing must be totally independent. So, we need different technologies to be able to offer us secure routing and transmission.

3.1 Virtual Routing and Forwarding

This is a technology that allows multiple instances of a routing table to co-exist within the same router. Concretely this technology is called *Virtual Routing and Forwarding* (VRF). A VRF consists of an IP routing table and a set of interfaces that use this forwarding table. With this technology, we can create in a router different routing instances, which are independent and also overlapping IP addresses (to use the same address networks) can be used without conflicting with each other. In this way, we can create as many ‘virtual routes’ as customer and services we have.

Figure *fig. 3.2* summarizes the VRF's features.

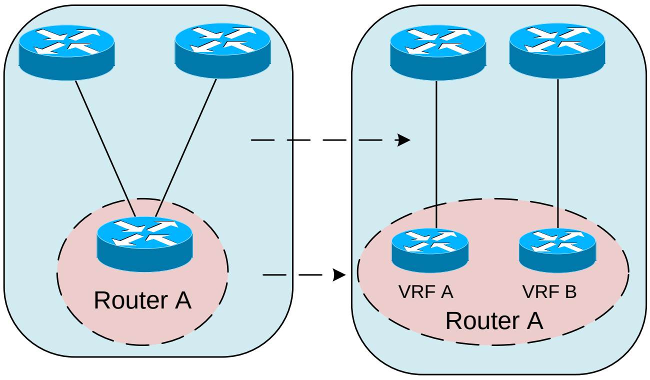


Fig. 3.2 Example of a *Virtual Routing Forwarding* in a Router.

We have to take into account that this feature allows us design a secure routing between our DataCenter and customers. In this way the customer will be able to put their address IP independently to the address of the rest of customers and services. The figure *fig 3.3* shows us the result of the logical design after to VRF implantation.

To improve the understanding of the VRF, we configured a small design of implantation of the VRF in two Cisco routers. It can see a small example in *Annex A*.

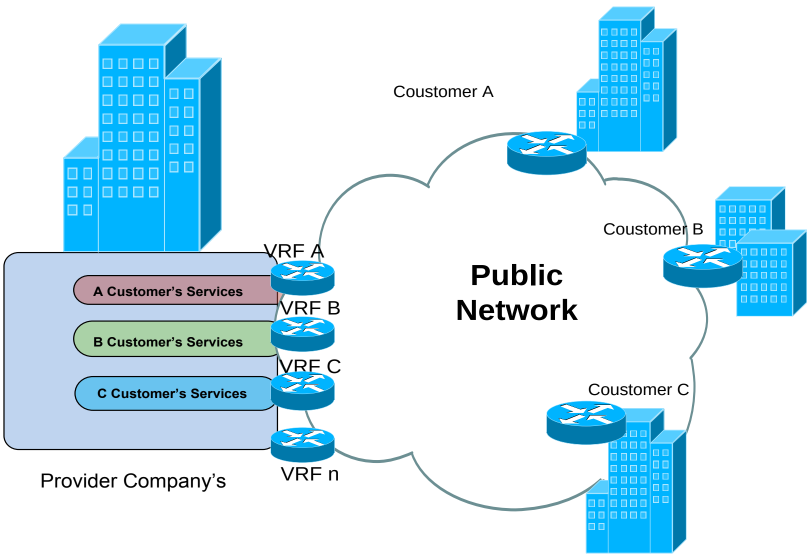


Fig. 3.3 Example of *Virtual Routing Forwarding* in *Datacenter*

In this project we are going to need use different operator networks to make connection with our customer through public networks. Therefore, the customers' information will be shared with other clients and, moreover, we need a transport technology that allows us have VRF visibility between customers and our DataCenter in this aspect.

How we can transmit private information between customer and our DataCenter using VRF technology, if the information goes over different networks? We need to search a solution.

Now, we are going to see that Multi Protocol Label Switching MPLS is able to offer us a scalable solution using all needed features that we described previously.

3.2 Multi Protocol Label Switching

Before explaining how we can to send VRF's over a WAN connection it is necessary to summarize the principal aspects of MPLS technology standard (RFC 3031)[10].

The thrust of MPLS is that packet forwarding is done by labels that are included in the protocol header. These labels are distributed between the routers MPLS through *Label Distribution Protocol* (LDP)[11], building *Label Switched Path* (LSP) between them. These labels, that are changing hop by hop, define a path (LSP) that has been calculated in advance by the network nodes and based on predefined criteria.

MPLS operates at an OSI Model layer that is generally considered to lie between traditional definitions of Layer 2 (Data Link Layer) and Layer 3 (Network Layer), and thus is often referred to as a 'Layer 2.5' protocol (See figure fig. *3.4*'). MPLS is an IP routing traffic technique, not a service. Therefore, it can be used to provide users from Virtual Private Networks (IP VPN) to ATM and even optical services.

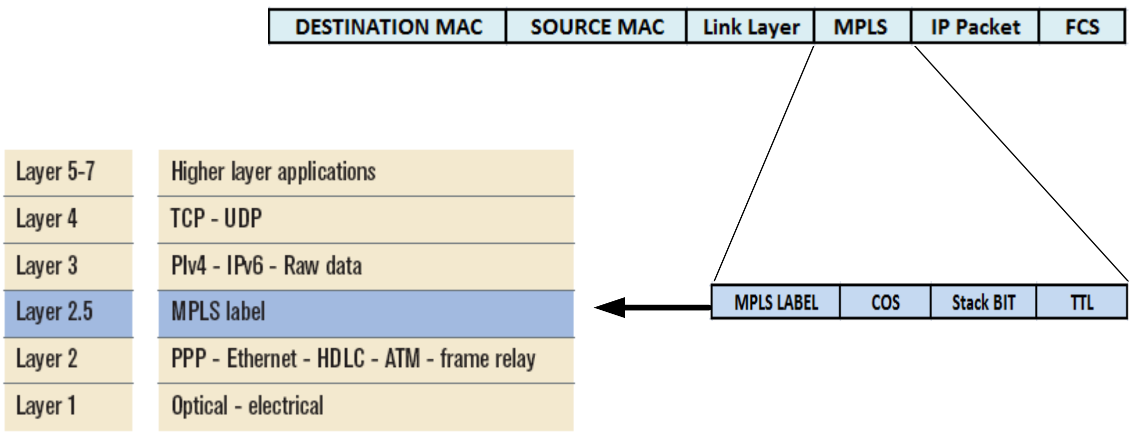


Fig. 3.4 MPLS compared with OSI Model

The points of entry into the MPLS network are called Label Edge Routers (LER) or Provider Edge (PE), in routers words, routers that have interfaces between the MPLS network and other networks. The router PE push an MPLS label onto an incoming packet and pop it off the outgoing packet. Routers that based only on the label are called Label Switch Routers or Provider Router (P).

The traditional IP packet transmission analyzes the destination IP address contained in the header of level 3 while the packet travels from source to destination presents some limitations: scalability issues, problems to support traffic engineering and poor integration with backbones of level 2 that are already implemented. MPLS solves all these limitations of traditional IP routing and enables new features such as VRF. In the figure fig. *3.5*' we can see in short, the elements commented previously.

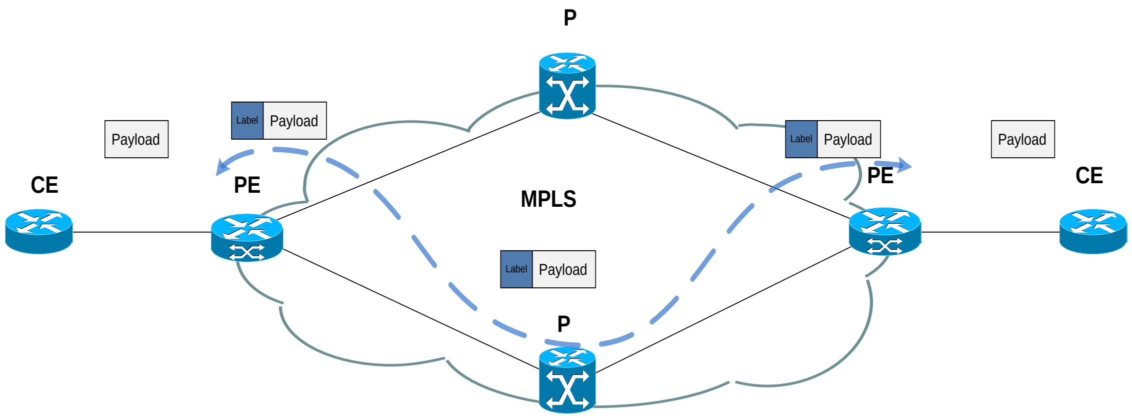


Fig. 3.5 MPLS network elements.

MPLS fuses the intelligence of routing with the performance of switching and provides significant benefits to networks with a pure IP architecture as well as those with IP and ATM (*Asynchronous Transfer Mode*) or a mix of other Layer 2 technologies. MPLS technology is a key to scalable virtual private networks (VPNs) and end-to-end *Quality of Service* (QoS), enabling efficient utilization of existing networks to meet future growth and rapid fault correction of link and node failure. The technology also helps deliver highly scalable, differentiated end-to-end IP services with simpler configuration, management, and provisioning for both Internet providers and subscribers.

It is so important make stress The MPLS VPN solution allows for traffic to be differentiated according to class of service (CoS) parameters over the backbone. The benefit of the class system allows for information going through the network to be prioritised based on the service selected. Each class of service comes with a set of service level agreements based on latency, availability, packet loss and jitter.

3.3 Virtual Private Network over MPLS

The MPLS/VPN[12] feature allows several sites to interconnect transparently through a service provider's network. One service provider network can support several different IP VPNs (VRF's). Each of these appears to its users as a private network, separate from all other networks. Within a VPN, each site can send IP packets to any other site in the same VPN.

Before discussing the security of virtual private networks based on MPLS technology (transport VRF trough WAN connection), it is critical to have a high-level view of how is offering this service.

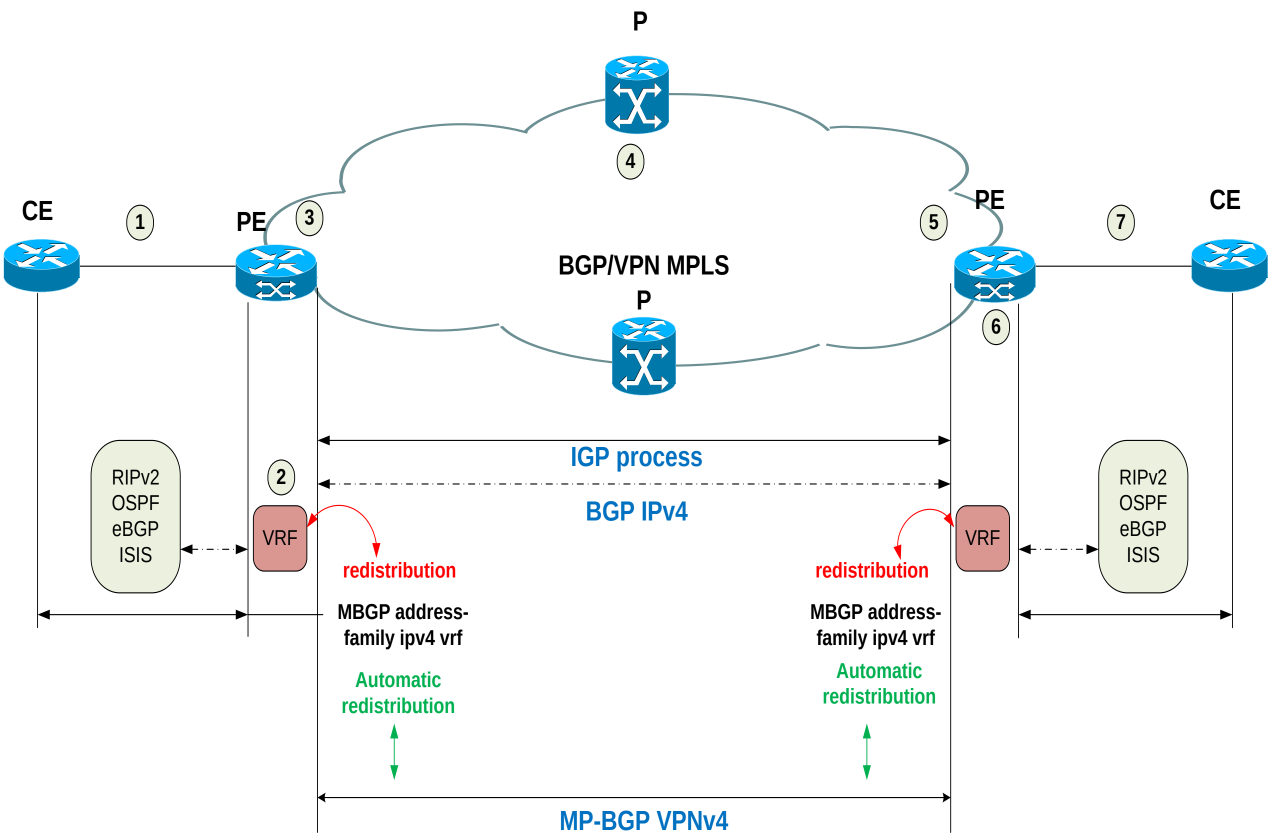
Each PE router can be connected to several routers CE. The CE routers are those that interact directly with level three (Layer 3 OSI) of the PE routers, which give access to the MPLS network. So, are unrelated to the existence of an MPLS network and do not understand the labels. Each PE router maintains a separate routing table for each VPN (VRF) in addition to a global routing. That is, if a PE supports the delegations of two different companies, it maintains two separate routing tables (VRF), one for each company and the global routing table, which allows the routing inside with MPLS core with itself.

PE router interface that connects to a CE must have an IP address within the address range of the VPN (VRF) to which it belongs the CE, so that the ISP is involved in addressing the company that provides service, but how we solve this problem will be explained later.

Following with explanation, each CE propagates routes from its routing table, to the PE (by an Interior Gateway Protocol (IGP)[13] or External Border Gateway Protocol[14] (eBGP)) and this in turn propagates to the CE routes that come from other PE's. The communication PE-PE requires further features. This is done via Internal Border Gateway (iBGP), due to that the routes are exchanged of all VPNs to which the ISP serves. BGP4[15] maintains a table of IP networks or 'prefixes' which designate network reachability among autonomous systems (AS). The router maintains a separate routing for each VRF. This prevents information being sent outside the VPN and allows the same subnet to be used in several VPNs without causing duplicate IP address problems.

Since two different companies, belonging to the same VRF, can opt for the same private address space, we should seek a mechanism to distinguish them. This is the goal of the *Route Distinguisher* (RD), which is nothing more than an extension of BGP (*Multi protocol BGP* RFC 4760 [16]), which is used when it propagates the routes between PE routers. It is important to note that P routers, which form the core MPLS network, do not participate in the exchange of VPN routes. They only run an IGP routing protocol among them and with the PE to exchange reachability information of the MPLS core, information to be used to distribute the labels to allow packet forwarding within the core.

In the Figure '*Fig 3.6*' we can see, in short, how MPLS/VPN works,



1. *IGP or eBGP advertises IPv4 route.*
2. *IPv4 is inserted into VRF routing table*
3. *IPv4 is redistributed into MP-BGP, rd is added to IPv4 route to make it a VPNv4 route.*
4. *iBGP advertises VPNv4 router with MPLs label and RTs.*
5. *RTs indicate to which VRF the route is imported.*
   Rd is removed from VPNv4 route.
6. *IPv4 route is inserted into VRF routing table*
7. *IGP or eBGP advertises IPv4 route.*

Fig. 3.6 Demonstrating of BPG and IGP protocols work in the VPN MPLS network.

Now that we know how to build the routing table, we need to know how to propagate different VPN packets across the network. When a packet arrives at a PE from a CE with a host destination of a remote delegation, it is encapsulated with the corresponding MPLS header. This header also includes two stack MPLS labels, the deepest identifies the VPN to which the packet belongs, and the outer label MPLS allows the network performs packet forwarding to the destination PE. Once the packet arrives at PE right, it is removed the outer label and the label is set deeper, which tells which VPN the packet belongs, and thus through CE interface should forward the packet. Finally, the CE is responsible to send the packet to the destination host.

In the figure fig. *3.7* we can see an example of a possible implantation of the technology commented previously.

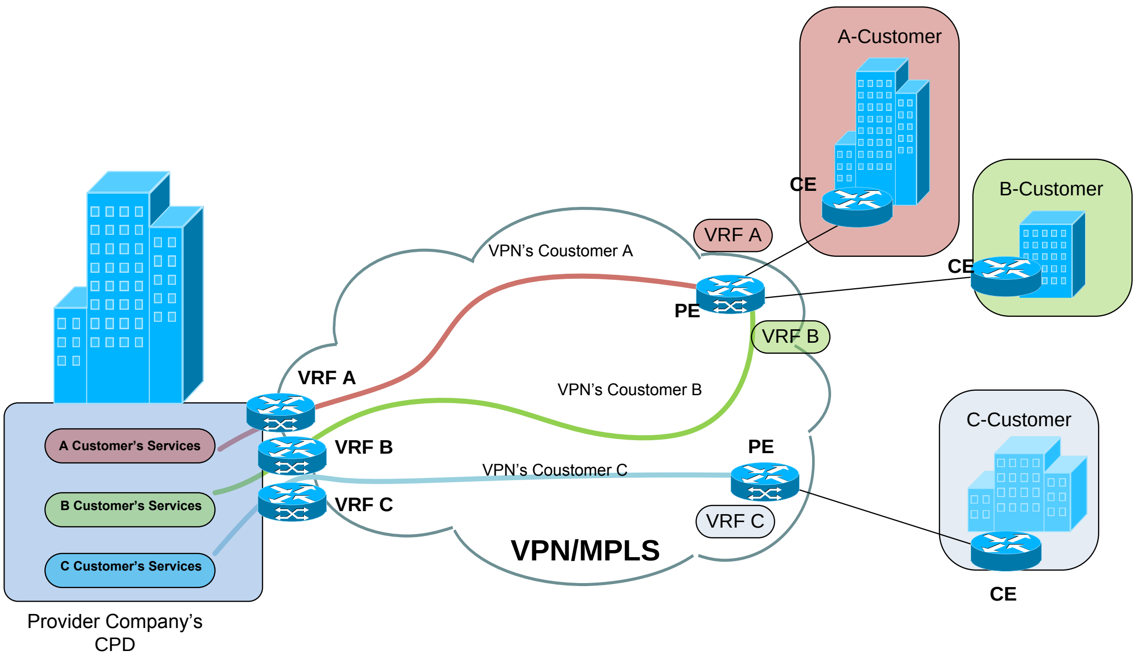


Fig. 3.7 Global vision of the MPLS/VPN connection between the customers and *Datacenter*

To improve understanding of the MPLS/VPN, I designed an implantation of the MPLS network with CISCO routers. These routers have been configured following all commented previously. See figure fig. *3.8*' that has been implemented and provided in *Annex A*

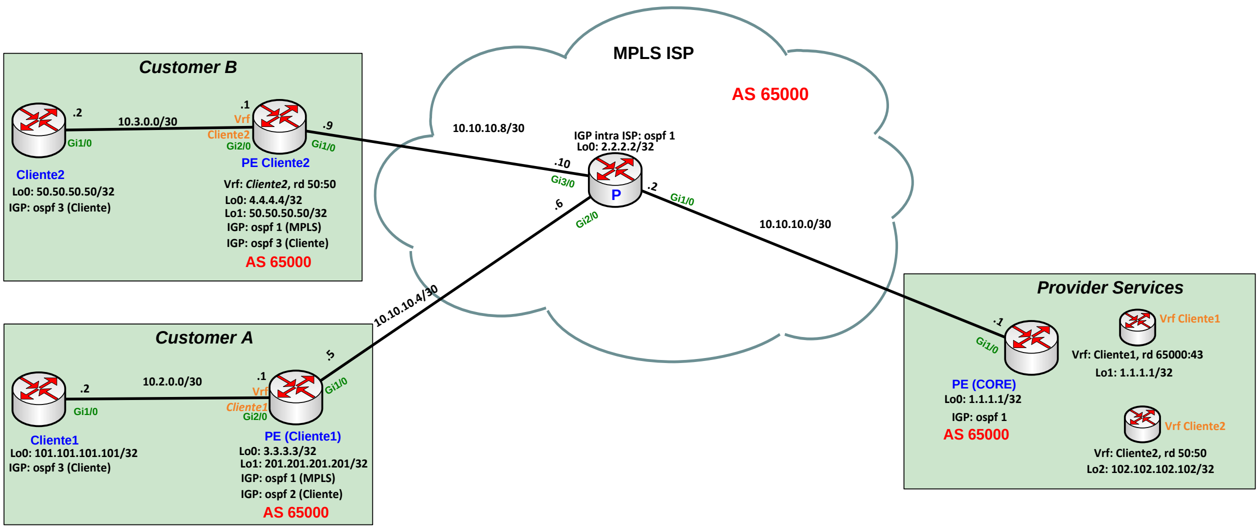


Fig. 3.8 MPLS/VPN scenario.

3.4 MPLS VPN Carrier Supporting Carrier

If you want to be an MPLS/VPN Service Provider and so, to build this kind of network, it is necessary to install hundreds or thousands of routers around the area you want to offer these services. This kind of deployments usually means the need to spend a lot of money and the fact of being able to use this infrastructure from someone else (the MPLS/VPN network from a service provider that already exists) at a reasonable price would be really interesting.

Let’s analyze what happen with a typical MPLS/VPN provider network. The MPLS/VPN Carrier network is formed by P, PE and CE routers. Between P and PE routers is mandatory to have an IGP routing protocol running on them. If the IGP stops working for any reason, the MPLS/VPN network do it so. That’s a really important thing to take into consideration because makes to reduce the chances of having any possibility to share any PE device between two service providers. Someone could thing about trying to get any kind of deal with a service provider that allow you to ‘own’ in a shared way any PE and so, to configure this devices. PE routers have the VRF definition and also one IGP instance running on each one of the VRFs against CE routers, and so, just being able to control PE and CE routers from an already deployed MPLS/VPN network, you would have the possibility to offer MPLS/VPN Services to someone else. But all of this is too much risky from the main MPLS/VPN provider point of view, it is not reasonable.

The *Carrier Supporting Carrier* (CsC)[17] design is the technology solution that faces with the problem explained before. This design is the one used to describe a situation where one service provider allows another service provider to use a segment of its backbone network in a transparently way. The service provider that provides the segment of the backbone network to the other provider is called the backbone carrier, in our case the ISP. The service provider that uses the segment of the backbone network is called the customer carrier, in our case the company that provider IT services.

The *Carrier Supporting Carrier* working is based on putting one or more VRF into another VRF, so that, the function of this last one will be to transport the other VRF. With this technology we can be independent from another ISP in VRF and IGP terms. Figure fig. *3.9* shows, in short, the comment previously.

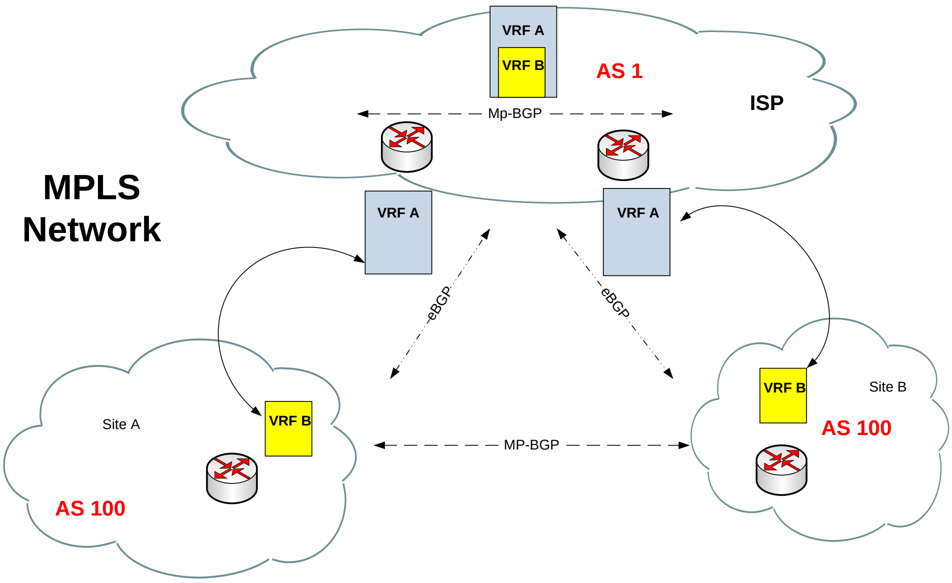


Fig. 3.9 MPLS/VPN CsC carrying VRF tables.

As we can see in the figure *fig. 3.9*, ISP is independent from Site A and Site B. With this design, it is not necessary the configuration of ISP's PEs for new customers and also our IGP would be independent (transparent) from the one of the ISP network. We emphasize that this aspect is the key achieve the real implantation of this project.

Thanks to this technology we can change the initial network proposed previously, since now this is really reasonable thinking especially about its operation, scalability and cost. Figure fig *3.10* shows the possible solution with the *Carrier Supporting Carrier* technology.

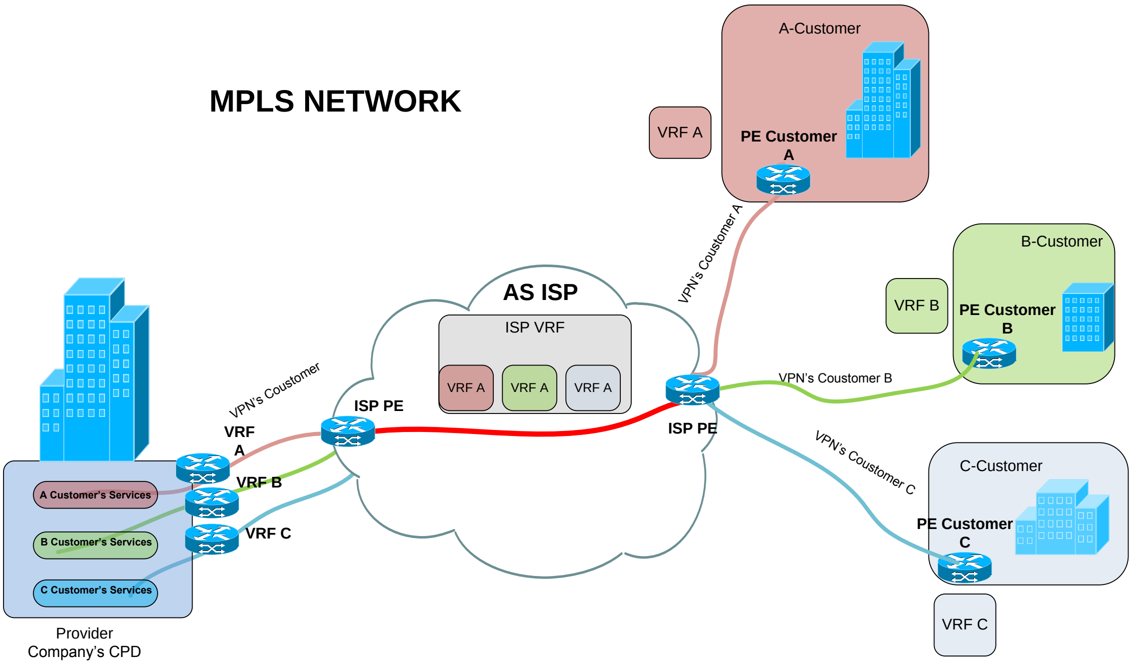


Fig. 3.10 Global vision of how CsC works transporting VRF tables between customers and *Datacenter*

3.4.1 Implementing the solution.

In this point we are going to design the solution commented previously. First we see a real situation, and we can proof that all previous hypothesis will be successful. Moreover, a global scenario is simulated in the ANNEX demonstrating that it is a viable solution.

3.4.1.1 Scenario

The scenario is composed by different customers, between them there are big customer composed by different sites. We, as provider company, offer to customers different services, total connection between their sites and secure connexions.

In a first phase, we would contact with an MPLS/VPN carrier, which allows us to arrive with MPLS to our customers. This ISP occasionally would contact with other ISP to arrive the network MPLS/VPN up to our customers with the velocity demanded by theses, but this would transparent to us.

After that, we send one or two routers at customer, depending if the customer has a basic router or not. In any case, we need that the customer has a PE router to connect at MPLS network.

In the figure *fig. 3.11* we can see the complete scenario.

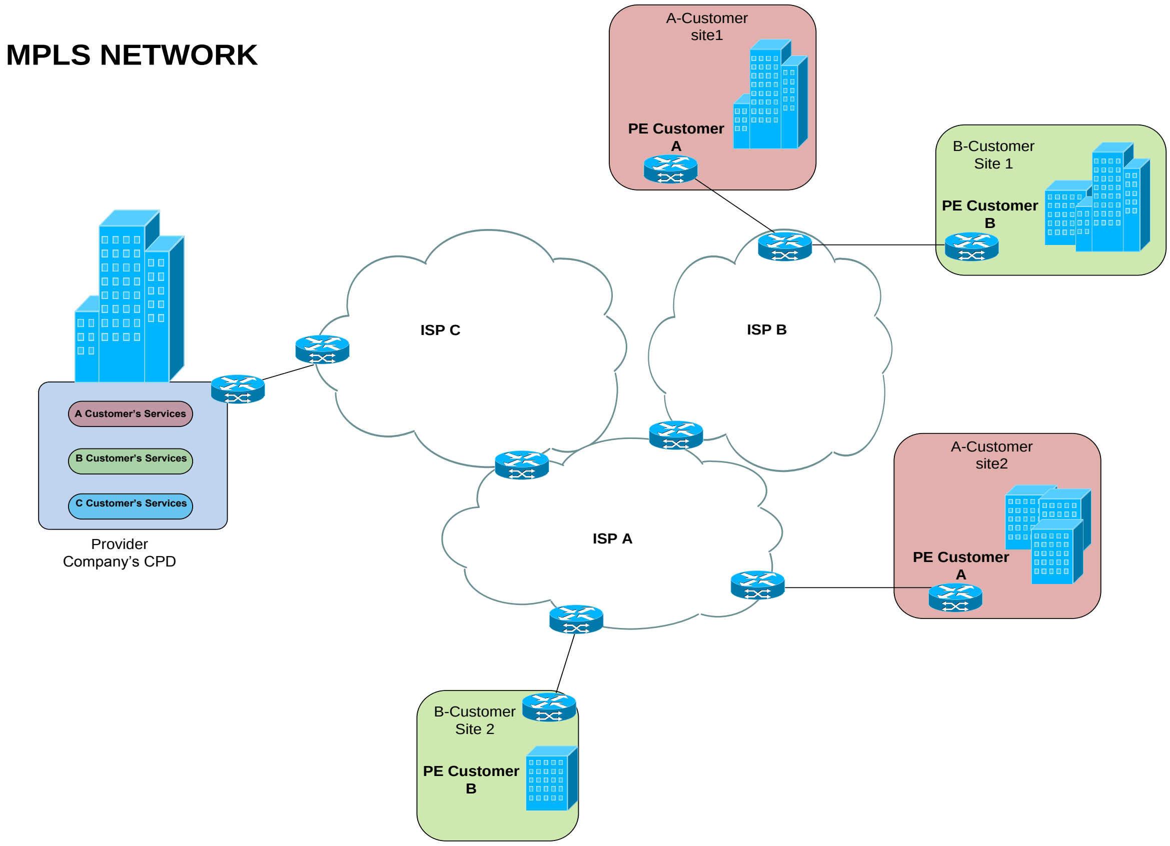


Fig. 3.11 The connection of *Datacenter* between different customers over ISP networks.

3.4.2 VRF deployement

We need that our hire ISP can offer us a MPLS network between our customers, also we have into account that the philosophy of CsC allows that the ISP do peering (the way that ISP have to share their networks between them).

Following the philosophy CsC, we need that the ISP make a VRF table and the *RD* that it puts was the same between ISPs that it make peering and us. This VRF will be used to transport the remainder of Customer's VRF. In this way, we can send the VRF Customers over the WAN secure connection.

Once we have the ISP VRF transport, we need to create a VRF that has all customers that we have services with us. These VRF will be configured in all routers PE of our customers. See figure *fig. 3.12*

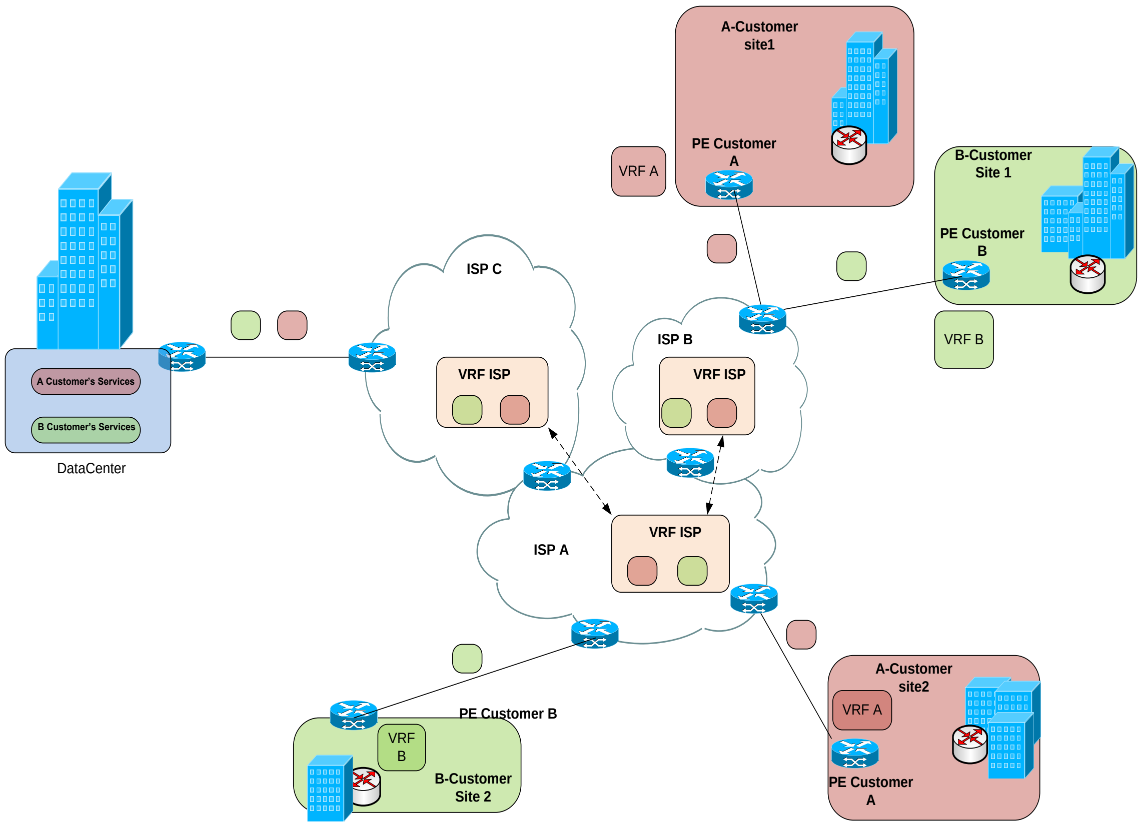


Fig. 3.12 Transmission of VRF Customer tables over ISP up to *Datacenter* in the proposed scenario.

3.4.3 Design the network

Now we are going to see in the figure *fig. 3.13* that it could be the design of the all network commented previously. It is important that to reduce the complexity of the simulation, the different ISPs have been reduced to one, for us this change is transparent

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Carrier Support Scenario based on Carrier VPN MPLS

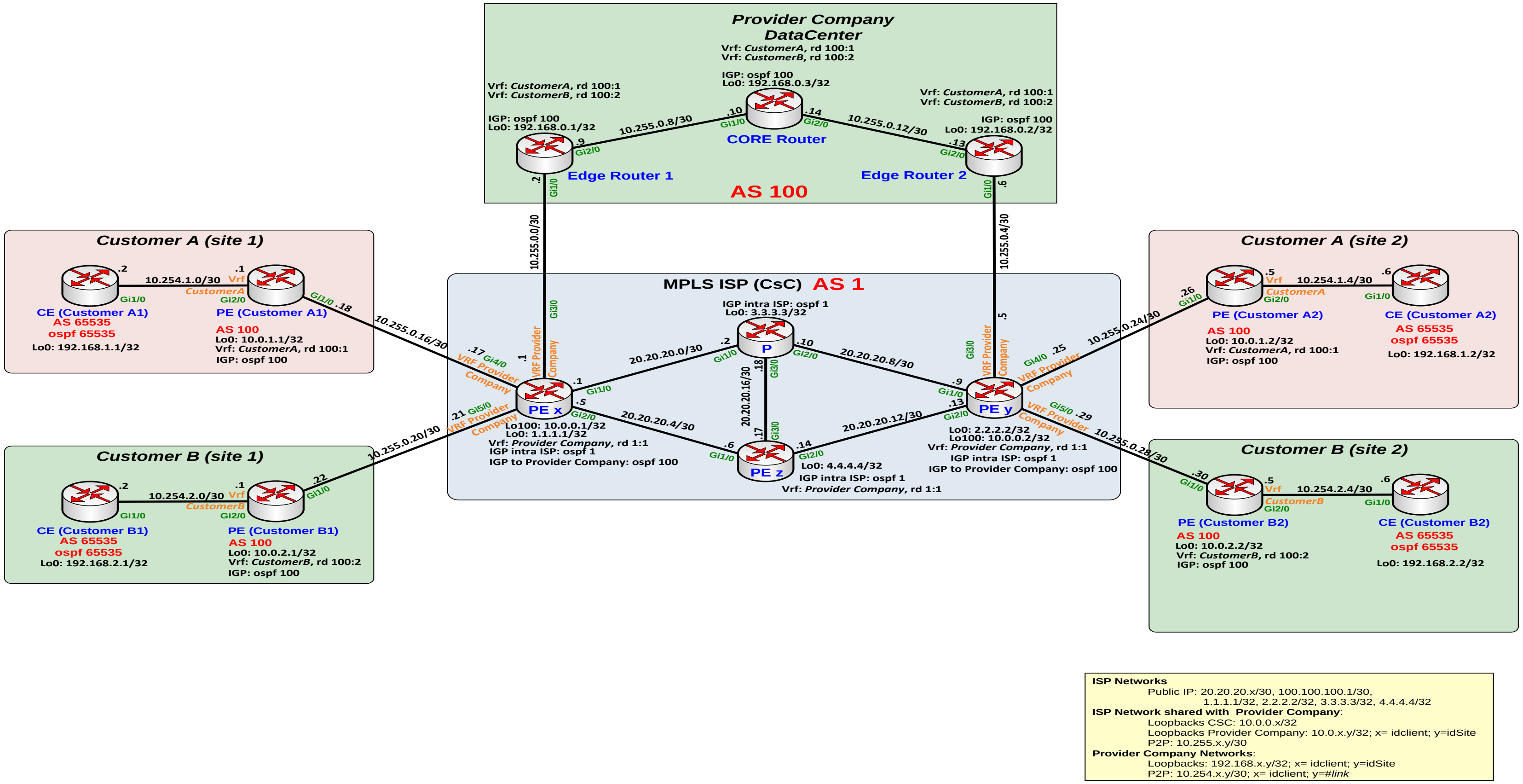

Fig. 3.13 BPG and IGP protocols deployment in the MPLS/VPN network proposed

We can see in the figure *fig. 3.13* the use of three routers in the *Datacenter*, with this one we get a high ability of the connection with the ISP and improve the hardware capacity of our Core.

Now we are going to show the use of the main protocols used in this scenario. See figure *fig. 3.14*.

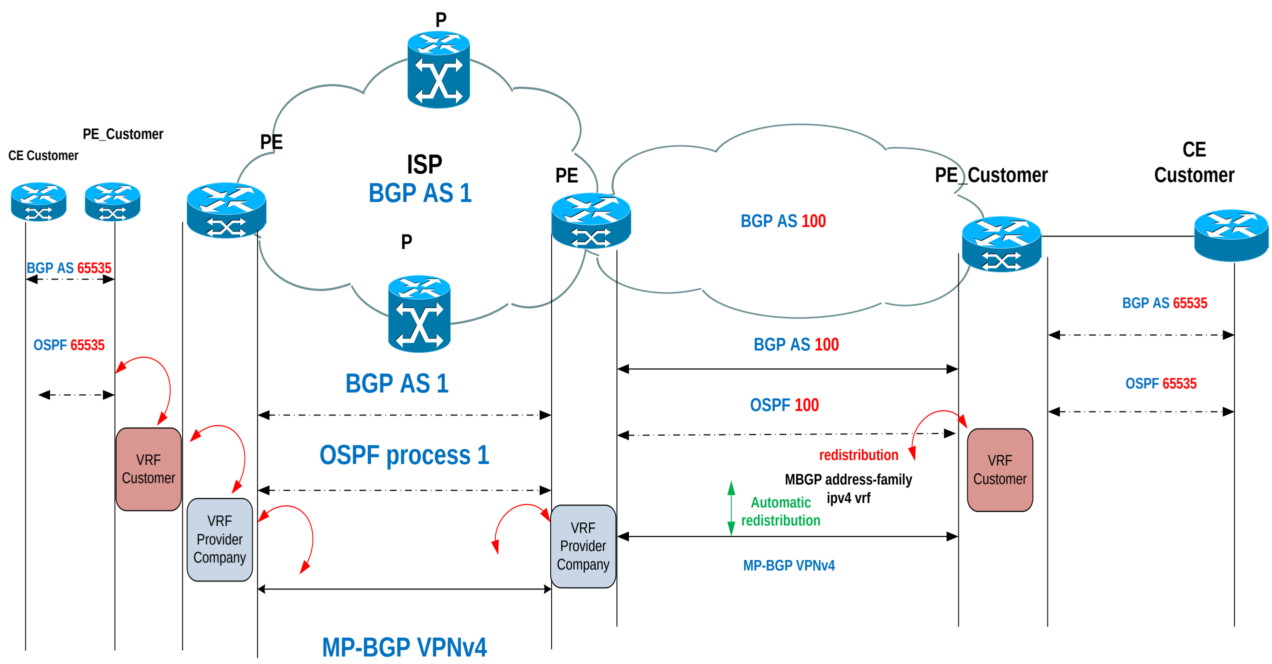

Fig. 3.14 BPG and IGP protocols deployment in the MPLS/VPN proposed network

As we can see in the figure *fig. 3.14* and scenario *fig. 3.13*, the provider company (AS 100) uses BGP to connect with the ISP and end to end OSPF (the process 100 of OSPF). The ISP (AS 1) also uses the BGP to connect with the others PE ISP routers.

This scenario is simulated with GNS3 software in the *Annex. A,* where it is shown all the work done. We implemented a real MPLS/VPN CsC network using a Cisco router simulator that showed that the solution proposed in this project was feasible.

CHAPTER 4. Design Operating Plan

Throughout this chapter, we are going to propose the procedure set when the client outsources their TI services in the *Datacenter*. Also, we are going to show of how this way of to offer IT services affects in the after-sales service and how would be the new chart of procedures and the new responsibilities.

4.1 Outsourcing Operational Plan

When we implement an operational plan based on the new model of outsourcing, the phases of action of each of the departments involved must be clear, the limitation of liability, definition of project scope and the SLA that is offered. It is also important to define the chronological order necessary for ensuring the proper implementation on both the client and the supplier company with a minimal impact.

The realization of such agreements involve a long process of maturation, since in many cases, it involves the transfer of ownership of IT assets and in some cases, the transfer of professionals. Therefore, developing a good plan that outsourcing is often more desirable and in many cases, is a key to the success or failure. Also, to adjust the contents of the contract and to define the scope of service, with mutual trust, are aspects to take into account when managing the transfer process. Thus, a system of shared management well developed, creating a relationship of mutual trust and commitment that can be responded flexibly to situations that can arise.

4.1.1 Keys to successful project outsourcing

In a outsourcing project we have to take into account different milestones along the deployment of services. The most significant elements keys are the next ones:

- Determining the range and scope of the project: defining technology (Networking, Security, upgrade technologies, ...)
- Human Resource Management: Defining dedicated staff or exported to customers.
- Management Tools: To maintain or integrate customer management in the supplier company.
- *Service Level Agreement* (SLA): Specify response time / resolution, bonus / penalty ...
- Period of transition: Defining delivery times, transition and objectives.
- Customer relationship model - Company: Limiting liability.

4.1.2 Recommendations to specify commitments

The key elements of a project have to follow some basic guidelines from standpoint of the interests of the supplier company. The different parameters of a possible contract must be analyzed carefully, since a very demanding parameter of part the customer or company may be result in not signing the contract, or otherwise the provider could never meet the specification and could be penalized.

Of all the contract, there are four that are very sensitive to variations:

- *Service Level Agreements* and penalties.
  - Must be demanding but achievable.
  - Adapted to the reality of the service.
- Transfer of personnel and assets.
  - Maintenance Contracts, Licenses, Hardware, etc.
- Period of transition.
  - Milestones and Deliverables.
  - Ensuring correct service.
- Termination of the contract.
  - Terms of exit.

4.2 Phases of an outsourcing project

To define the different parts of an outsourcing project is important to make the definition processes in a chronological order from their presentation to the expose of the offer.

The implementation of this project has be divided primarily into two very distinct phases, one in which aims to present a financial offer to the client and a second which aims implement the agreed services. In the last phase is to consist with a final process called ‘devolution’ which is based on the devolution of the services to a third supplier. In this process is intended that the client knows that if he decides to terminate, the provider will must facilitate the migration process by providing documentation and qualified personal while the longer process is executed.

4.2.1 Business phase

This phase is divided into three parts:

- Presentation of the offer or tender
- Award
- Audit Service

In figure *fig. 4.1*, we can see a resume of the commercial parts phase.

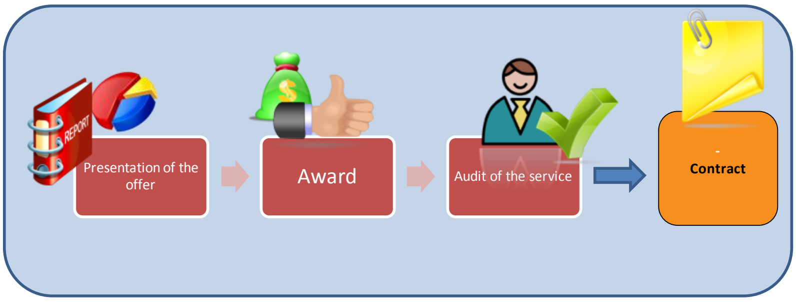

Fig. 4.1 Business phases

The presentation of the offer is the phase in which the commercial agents of the company want to award the contract, offering a technical and economic offer to the customer.

The award is the phase in which the customer accepts the financial proposal between all the proposals.

The audit of the service is the procedures undertaken by the customer to verify that the all information is real and it is adjusted at the economic proposal and to reality. Usually occur at this stage the changes of the initial phase, for example the price, SLA's, etc.

4.2.2 Implementation Phase

In the implementation phase there is a transition between the sales department and operations of the supplier company. This is the stage where it is explains what has been sold and it is included in the contract. It is imperative, to a proper understanding of the parties, the effective use of the feedback.

This phase is comprised of five parts:

- Launch
- Transition
- Transformation
- Outsourced services
- Return of services.

In figure f*ig. 4.2*, we can see a summary of the parts of the implementation phase.

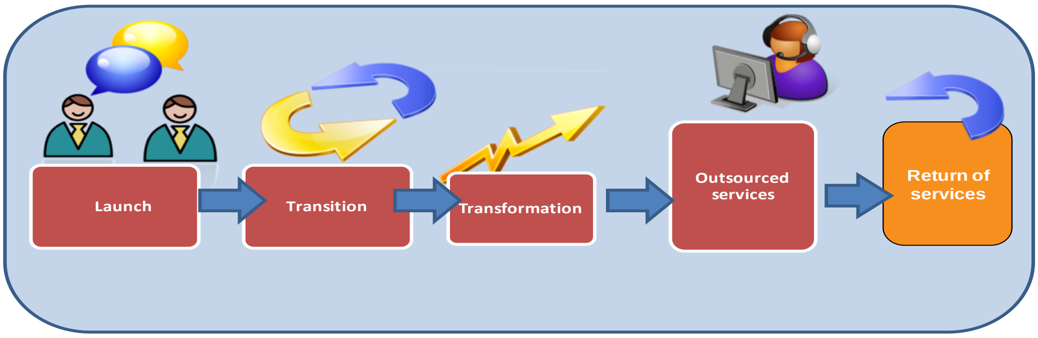

Fig. 4.2 Implementation Phase

The launch phase is based mainly on the transfer of information between the current responsible. In this phase will be agreed the involvement of various parties in the parts of this stage. Moreover, the engineer, assigned of the project, will plan with detail the transition of the service.

The Transition is the most critical part of the implementation phase, specified therein:

- The duration of the transition, which is variable depending on the type IT services included in the contract.
- Assumption gradually of the service through the existing technical documentation.
- Transfer of service and assets from outsourcers or the company itself.
- Risk analysis and study of the backtracking.
- Definition of monitoring reports and metrics of the service.
- Parameterization of tools for integration with the Managed Services of the provider company.
- Parameterization of tools for integration of customer's IT infrastructure with the company's infrastructure.
- In this phase, there are not apply Service Level Agreements and the penalties associated.

The **Transformation** phase is the part that performs the transformation of services, in which the client starts to have managed and outsourced much of its IT infrastructure in the supplier company. At this stage specifies that:

- Application of penalties associated.
- Variable duration depending on the service contracted.
- Ensuring continuity of service with location of the *Managed Services Center* and *Datacenters* in high availability.
- Platform Managed Services and Operations of the supplier company at the service of the customer (methodology, service model, tools and experience).

The phase of **Outsourcing** is when we have successfully outsourced and management the services to the supplier company. This is where the responsibilities of supervision and proper operation come back to the supplier company. In this phase, there are apply *Service Level Agreements* and the penalties associated.

It should be stressed that there must be a final phase of the return of the services, in which provides the customer a possibility of change to other service provider in a future. At this stage is specified the following:

- Ensuring continuity of service with the utmost care until to another provider, or the customer, assumes the control of the service.
- Maintenance, during this phase, of the Service Level Agreements and availability levels of IT services included in the agreement.
- Delivery of all necessary documentation (procedures, drawings, technical information) to the new supplier.
- Offer the possibility of installing all the services that has been outsourced in the customer's infrastructure, with a considerable discount on the price.

4.3 Advantages of the operational plan with the new model of outsourcing.

It should be stressed the main operational advantages that the new model gives compared with other models.

To outsource most of the IT assets as well as management give big advantages not only to the commercial phase but also to the implantation phase. At the same time, allows the possibility of appearing new services.

4.3.1 Business Phase

With the new business model, in the commercial phase, the commercial agents trade may offer better financial offers because they haven`t the need to sell all the necessary hardware, as this will be rental by a kind of ‘renting’ and outsourced the customer's infrastructure in to the supplier. In this way, it provides a best first access to the customers reducing them the risk of initial investment.

By offering this service model, including better prices and less investment risk, would broad spectrum of potential customers. It is also important to note that considerably reduce the time and the need for meetings between the commercial and operations departments, due to we are offering them own technology.

4.3.2 Implementation Phase

It is very important to stress on fact to have an IT infrastructure gives as result a highly specialized technical personnel. This is the key to ensuring the functioning of services and SLA's agreed. Moreover, we have take into account on fact that we will not need a longer and expensive interventions in client's company when is necessary to upgrade the customer's services, since only will be necessary to adapt our IT structure for the client.

4.4 Conclusion

The new outsourcing model provides us an innovative idea that differentiates us from the competition. Facilitating the access to high technology at companies, that, previously, they could not make it due to big initial investments, introduces a new way to offer service that, at the same time, it ensures a customer loyalty. This is due that the customer's services will be in the provider, in this way it will facilitate us the sale of new IT services.

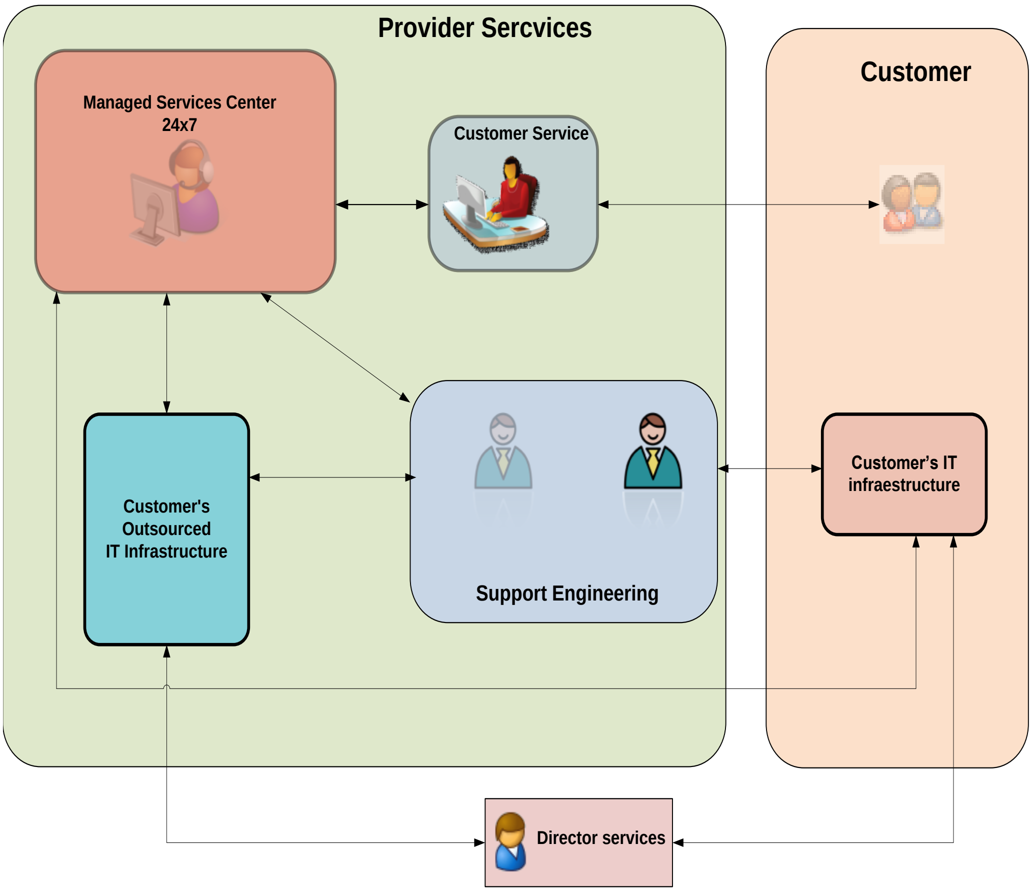

Fig. 4.3 Model of support and operations services post-sales

In the figure *fig. 4.3* is summarized the new model of support and operations, which will be at a level in keeping with the needs and priorities of the outsourced customers. In that model, there will be two types of infrastructure, outsourced and customer. The department will give support at all services agreed by the customer, which normally it will be located mainly in the provider company and the indispensable part in the client. For each customer there will be a service manager, which it will be the responsible for ensuring compliance with the agreed services.

CHAPTER 5. Business Benefits

This chapter will show the sufficient information to justify the goal of the Project, which is to facilitate at SME and big enterprises the IT access to simplify management, technological complexity such as cost of the procedures, and IT infrastructure, by externalizing assets and technological services.

5.1 IT Business market

The idea of this business is based on to facilitate the access to IT of the companies by introducing a new model of outsourcing, which allows transfer a big part of the customer's IT infrastructure in the supplier company through of the *Datacenter* and WAN connections. In this way, the customer gets, by reducing the initial investment, expedite the internal procedures, the needed of to get highly qualified personnel and get a integral solution of services IT.

Thanks the new model of outsourcing, the organizations become more agile, flexible and more operational, eliminating any operational problem and brakes to economic growth.

In the figure *fig. 5.1* we can see a summary of the IT solution that would be offered at the customer through the new model of outsourcing.

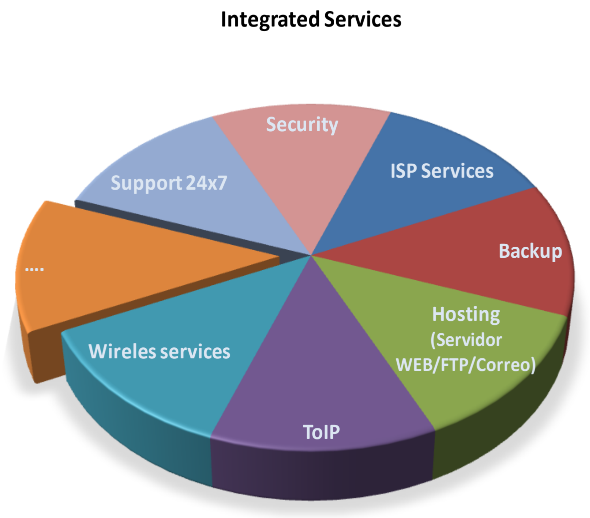

Fig. 5.1 **Global IT services.**

5.1.1 Target group

The potential customer is comprised mainly of SMEs and big companies that discouraged by the initial investment, the need of to have qualified technical personnel or the complexity of managing, they don't make a IT investments.

According to the article of June 25, 2009 of the electronic magazine info technology[19], around 50 percent of SMBs are planning to invest in IT this year. In addition, we observed almost 50% of companies, mainly for economic reasons and complexity, they don't make such investments. Therefore, we have a large niche of potential customers by which had not yet been raised to have advanced IT services, and the case that they are willing to invest, we would have a more flexible, scalable and cheaper product than the competition.

5.1.2 IT Situation

When it comes to offering a new type of service, it is necessary to make a market study to know the state of the market in order to know what your needs and if our new service could respond to the current situation of IT.

To know the status of IT, we have based in the publication that made the company ASIMELEC. According to the report, the year 2008 has been a year marked by the change of the economic cycle. After several years of substantial growth of all markets in the IT's sector, 2008 has seen, at the best, the slowdown of theses growth. Still the overall result for the year for all ITs sector can be assessed as moderately positive.

According to the report, the telecommunications equipment sector has achieved a turnover in 2008 of 6.328 million Euros, representing a decrease of 6.4% compared to 6.759 million Euros in 2007.

As we can see the investment in IT by business environments suffered a stalemate over the previous year. This data motivates the fact to innovate to go more into the 'niche' companies that want to enter the IT world but they do not have enough capital and technical staff.

5.2 Benefits of IT outsourcing

By definition we understand the IT service outsourcing when the client delegates a certain area of their IT services to a third party, in order to better position the organization in one or more aspects. In our case, the customer provides us much of the IT hardware in your facility to transfer them in the provider.

The use of outsourcing as a strategic tool is based in the needed of the organizations to become more agile and flexible operating in an environment characterized by uncertainty as a structural variable.

IT service outsourcing arrangements are pro-competitive, they enable customers to benefit from high-tech services provided by specialized providers, rationalize their cost structure, by transforming fixed costs into variable costs and reducing capital invested. And use their own resources more efficiently by focusing on their core business, thus enhancing their product and service offerings to final consumers.

5.2.1 Reasons for outsourcing

In recent years, we are witnessing a generalization the outsourcing of IT. The outsourcing has spread to different application areas. Traditionally, the focus on main business activities and cost reduction were the main arguments that led companies to opt for outsourcing. Currently, to these reasons must added as increasing technological complexity, improving overall efficiency and the geographical dispersion of users, etc..

The following figure summarizes the main motivations of the companies to demand outsourcing services of TI.

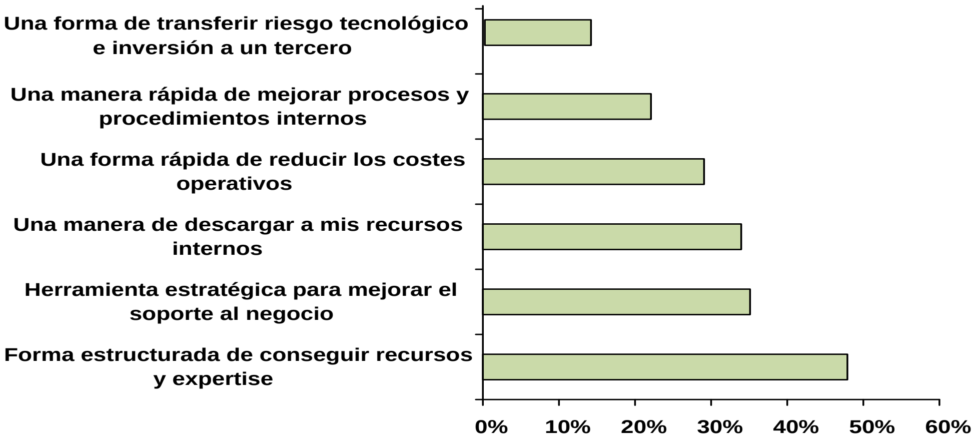

Fig. 5.2 Main motivations of the companies to demand outsourcing services of IT by *Unitronics.SA*

According figure *fig. 5.3*, one of the most important reasons for companies to demand IT service outsourcing, is the difficulty to found specialized resources and their use as a strategic tool to improve business support.

5.2.2 Differences with other externalization models

To better understand the new outsourcing model we must make clear the models currently used by companies.

Traditional model based on people management

This model is based on the ‘sale’ of qualified personnel from the supplier company to the customer. Staff works directly in the infrastructure of the applicant and is fully integrated into structure of the client.

This model has the follow, advantages:

- Staff works directly in the site of the customer. So they have high implication and specialization.
- The customer has not the difficulty to found specialized resources.

This model has the follows disadvantages:

- Holidays Staff and problems derivates of to be on leave (sick leave, family leave, maternity leave, injury leave).
- The customer manages all infrastructures.

Model based on service management outsourcing

Model based on service level agreements for the management of infrastructure. This model is based on service. See figure 1.1.

This is a form of service outsourcing with a more focused and concretes that outsourcing, assuming a standard model without a transfer of assets or business. In short, "is the response of service providers to market demand for medium-sized accounts that request services in specific areas.

Model based on IT outsourcing and service management

This is the model proposed by the project, which is based on maintaining the advantages of model based on service outsourcing management, but at the same time, outsourcing the maximum IT infrastructure of the customer, by placing it in the Datacenter of the supplier.

To better understand the advantages and disadvantages of different models from the point of view of the customer see figure 1.2.

5.2.3 Responsibilities of the service providers

Based on the new model of outsourcing the supplier has new responsibilities, which could emphasize the next aspects:

- Management of human resources and equipment necessary to provide the service.

- Full responsibility for the service undertaken.
- Compliance with Service Level Agreements (SLA).
- Penalties for breach of Service Level Agreements agreed.
- Flexibility and responsiveness to demand fluctuations.

5.3 Main economic benefits of outsourced services

At this point we go to show enough data to demonstrate that the outsourcing model, commented in this project, facilitate, financially, access to incorporate the IT at their companies.

5.3.1 Advantages of renting

The outsourcing model discussed in this project bases its main benefits in the foundations of the concept of "technological renting". These are their main advantages:

- It allows access to latest technology without the need to make large initial payments.
- The company receives and integral service covering all possible investments: hardware, installation, maintenance, training, etc at a fixed rate during all the renting period.
- All services required for operating the infrastructure are included in the financing.
- Economic resources that need continuous renewal are not locked-up.
- Renting fees are 100% fiscally considered as business expenses.
- It is possible to renew, increase or substitute parts of the infrastructure during the renting period by simply adjusting the monthly fee.

5.3.2 Investment in IT without a outsourced model

Is important to highlight that any implementation of an IT project has are two types of investments:

- **Initial (CAPEX**): a large initial investment which is usually destinated for new hardware and licensed software and the adaptation of the company's infrastructure. Their high prices are usually the main reason that SMEs and large enterprises, with financial problems, dare not access IT.

  Fixed (OPEX): this fixed costs necessary for the administration, management and preserve the IT services. For the proper maintenance, is essential to have highly qualified technical personnel on staff. The difficulty and cost of finding this profile is one of the handicaps before making an investment in IT.

5.3.3 Investment in IT with an outsourced model of services and IT assets.

By outsourcing asset and service IT, the new model would offer the following types of economic benefits in the two types of investments:

- **Initial**: It had a significant difference compared to other models with the absence of a costly initial investment, because the hardware and necessary licenses could be rented. Only a small initial investment would be needed to adapt the company to receive through WAN connections the IT services.

- **Fixed**: the management, technical-administrative and maintenance would be carried out remotely from the provider, therefore the fixed cost of these services would be substantially reduced. All internal procedures related to maintaining services IT will be reduced or eliminated .Is important to note that technical personnel remotely will manage of the services, they will not dedicated exclusively to any customer, only where it was requested for this.

5.3.4 Conclusion

In conclusion, we can see how the new model of outsourcing can influences in the reduction initial and fixed costs. Nevertheless we should take into account the emergence of the monthly / annual cost of the renting technology.

CHAPTER 6. Conclusions

At the beginning, my main concern before starting this project was to find some business ideas related with the IT world that could be seen interesting by the company where I was doing the fellowship. I had the challenge of finding not only and interesting idea but also something that could be really implemented by the company.

Along this project, I expose the feasibility of a new technological outsourcing model and how it can be developed from business and technical points of view.

The business vision is compliant with the following points:

- Unifying a wide range of technology services in a ‘single product’ and at the same time being able to provide them to the customers in an affordable way.
- Minimize the client’s initial economic impact when asked for the introduction of an IT service, reducing the deployment of new hardware and installation procedures.
- Minimize in our clients the cost of maintenance and equipment management.
- Minimize qualified technicians on the client side.

After all, we are proud to say that on one hand, we were able to find an interesting business solution (at least, that’s what the company said), and on the other hand, we also achieve the goal of learning new technologies and to get something implementable, which really motivated us to undertake this project.

The fact of starting the fellowship with almost no networking idea force me to mention the hard effort I had to do to get the appropriate knowledge level to go ahead with this project. The Cisco routers simulator (GNS3) is the tool that let me settle all this knowledge and also the one that I have use to show the viability of the connection between sites that the show business idea requires.

6.1 Future Work

The following step of this project would be to do a more in-depth technical design of the proposed *Datacenter*, since the purpose of this was to introduce a new model for providing IT services showing the business benefits and examples.

Also would be required to conduct a comprehensive economical study on the overall project

6.2 Environmental impact

The fact that many companies outsource IT services and assets into a single virtualized point (which is being reused and shared by other clients) provides major environmental benefits due to not having to deploy multiple devices associated with a single service.

Also note that having the infrastructure in the supplier avoids most of the travels between provider and client and makes easier the reuse of technology while minimizing the companies' internal procedures.

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ANNEXES

A. Scenarios

What is GNS3 ?

GNS3 is a free graphical network simulator that allows simulation of complex networks.

To allow complete simulations, GNS3 is strongly linked with:

- Dynamics, the core program that allows Cisco IOS emulation.
- Dyanagen, a text-based front-end for Dynamips.

GNS3 is an excellent complementary tool to real labs for Cisco network engineers, and technical managers. It can also be used to experiment features of Cisco IOS or to check configurations that need to be deployed later on real routers.

Features overview

- Design of high quality and complex network topologies.
- Emulation of many Cisco router platforms and PIX firewalls.
- Simulation of simple Ethernet, ATM and Frame Relay switches.
- Connection of the simulated network to the real world.
- Packet capture using Wireshark.

Scenario VRF

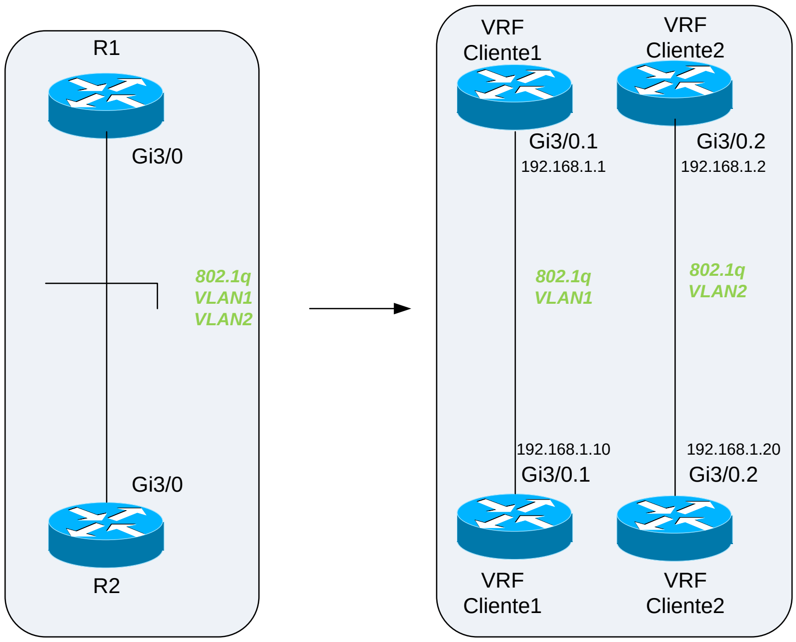


Fig a.1 Vrf scenario

In the figure X.X we can look a simple VRF based on two routers Cisco with VRF configuration. They are connected with between by links dot1q[]. The scenario is implanted in GNS3, as we can see in the figure X.X.

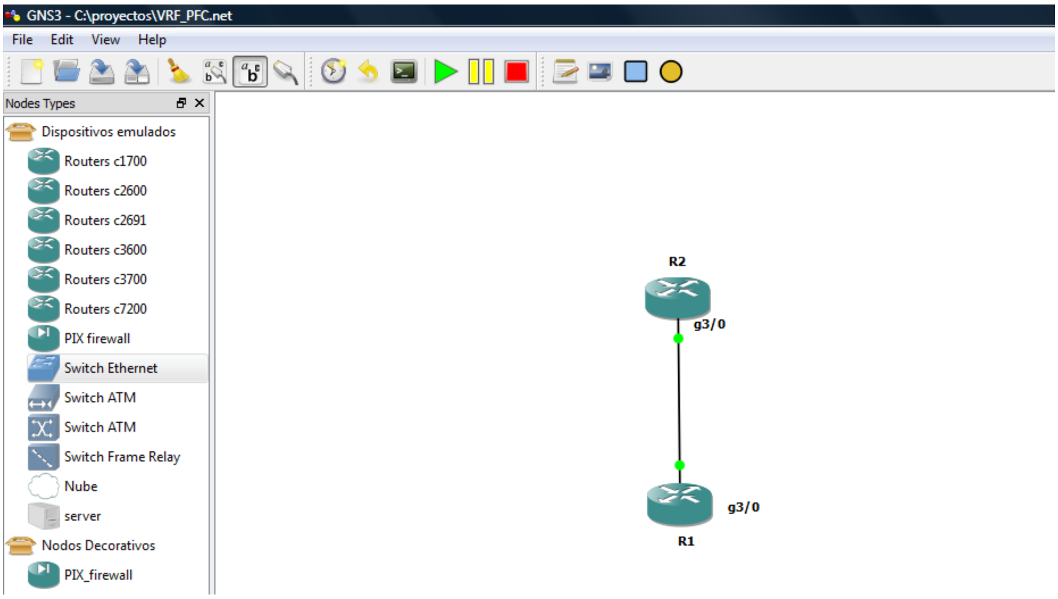


Fig a.2 GNS3 Screen shot

TEST

In this section we can see how the different virtual routers have not visibility between them. To show this we are going to do pings between the VRFs showing the IP visibility.

R1#Show ip route

```
R1#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

R1#
```

There are no IP routes

Now, we are going to do ping between the routers VRF Cliente1 and Cliente2.

R1#Show ip route vrf Cliente1

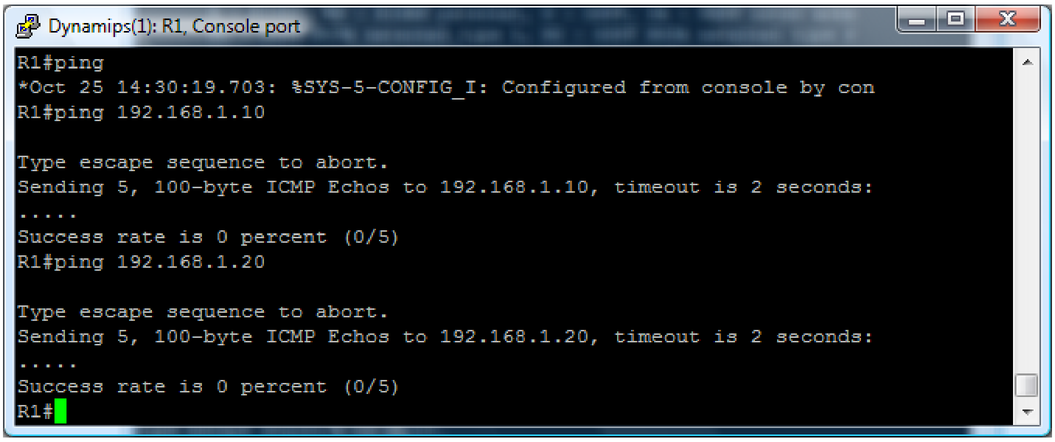
```
Dynamips(1): R1, Console port
Routing Table: Cliente1
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.1.0/24 is directly connected, GigabitEthernet3/0.1
R1#
```

```
Dynamips(1): R1, Console port
Routing Table: Cliente2
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.1.0/24 is directly connected, GigabitEthernet3/0.2
R1#
```

We can see VRF Cliente1 and Cliente2 routes.

In the next figures, we do pings from R1 to R2. Note that we cannot make pings between them, because the R1 has not the routes to arrive at R2. If we specific VRF that we want do the pings from the adequate VRF, we could do the pings.

R1#ping 192.168.1.20
R1# ping 192.168.1.10



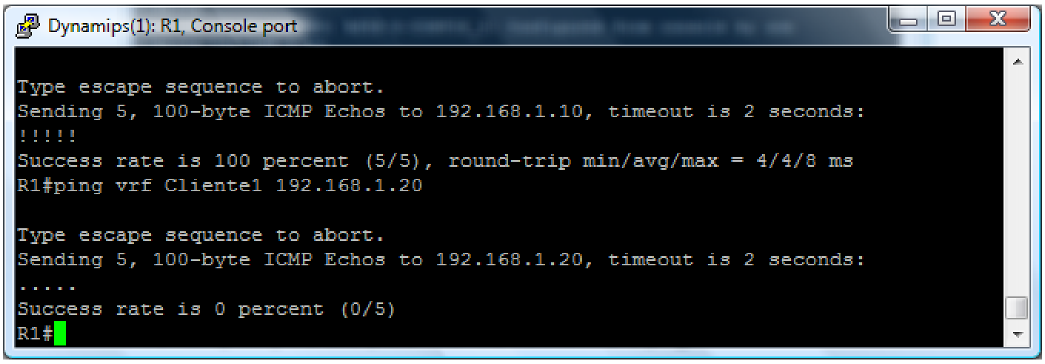
Dynamips(1): R1, Console port

```
R1#ping
*Oct 25 14:30:19.703: %SYS-5-CONFIG_I: Configured from console by con
R1#ping 192.168.1.10

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.10, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
R1#ping 192.168.1.20

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.20, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
R1#
```

If we not specify the adequate VRF we cannot make pings.

VRF Cliente1 ping → VRF Cliente1 and Cliente2

R1#ping vrf Cliente1 192.168.1.10
R1# ping vrf Cliente1 192.168.1.20



Dynamips(1): R1, Console port

```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.10, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/8 ms
R1#ping vrf Cliente1 192.168.1.20

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.20, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
R1#
```

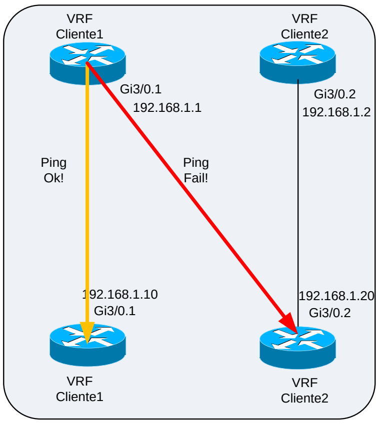
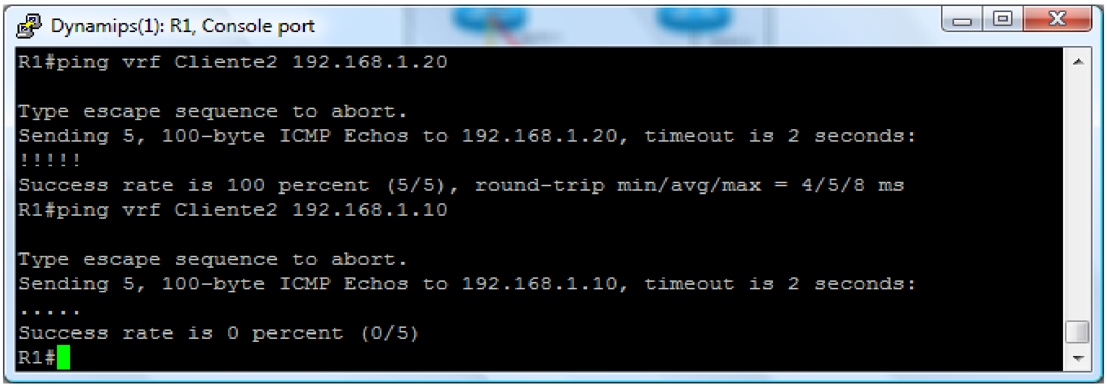


Fig a.3 Success and fail pings

VRF Cliente2 ping → VRF Cliente1 and Cliente2

R1#ping vrf Cliente2 192.168.1.20 **R1# ping vrf Cliente2 192.168.1.10**



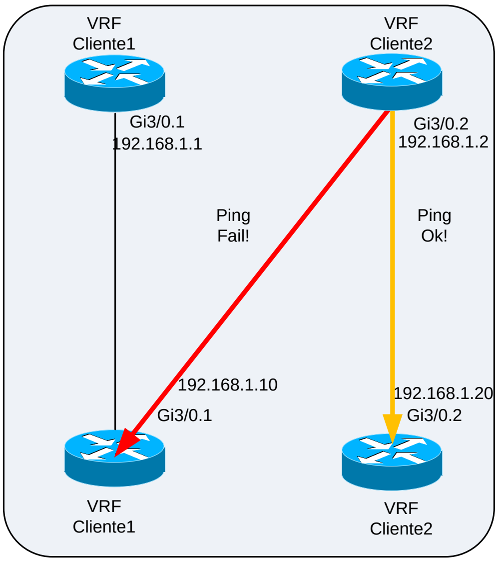


Fig a.4 Success and fail pings

Scenario VPN MPLS

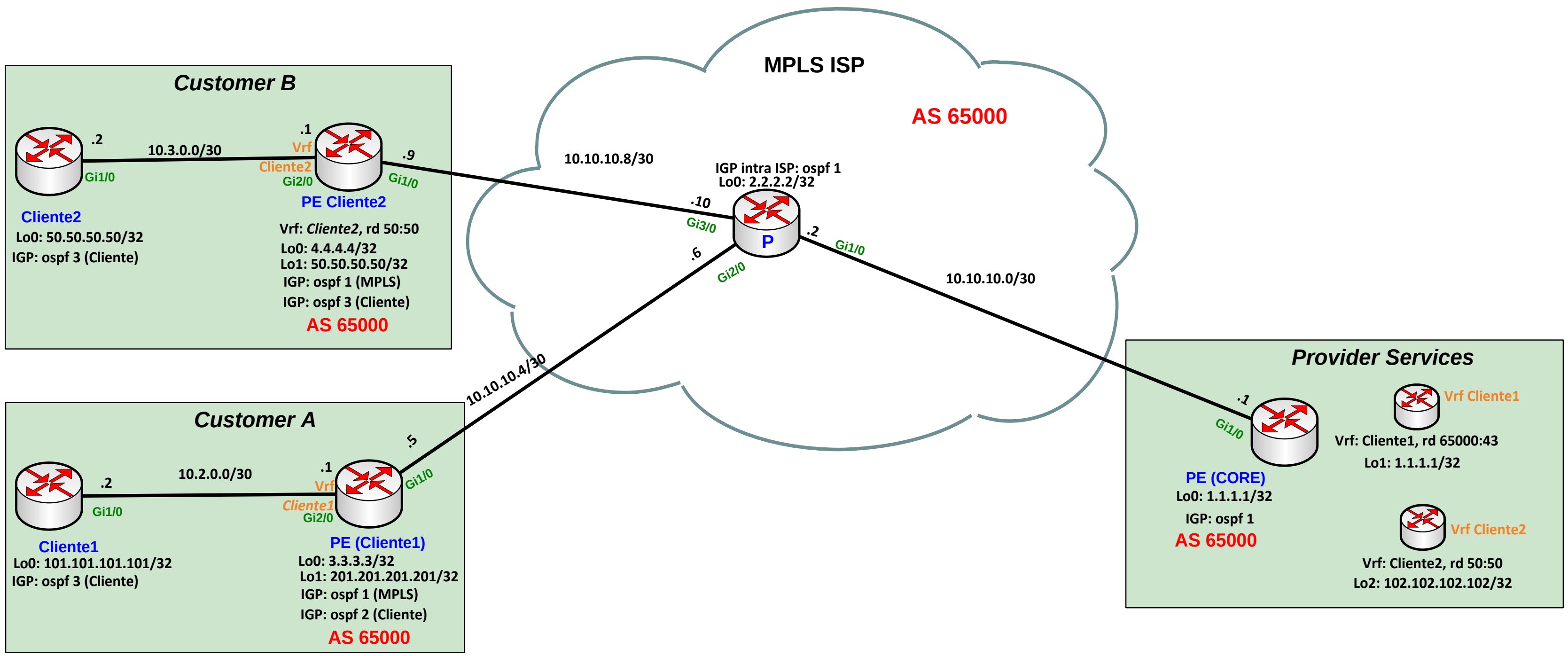


Fig a.5 VPN MPLS scenario

Figure *fig. a.5* shows the MPLS/VPN network designed which has the goal to demonstrate the proper functioning when sending sensitive information via WAN. As we can see all PE share the same AS process, this could be a possible and real solution if we were an ISP. Now we are going to look the scenario behaviour and to observe if the theory is implanted in the practice.

Once we have made the design of network we go to implant in GNS3 (see figure *fig. a.6*

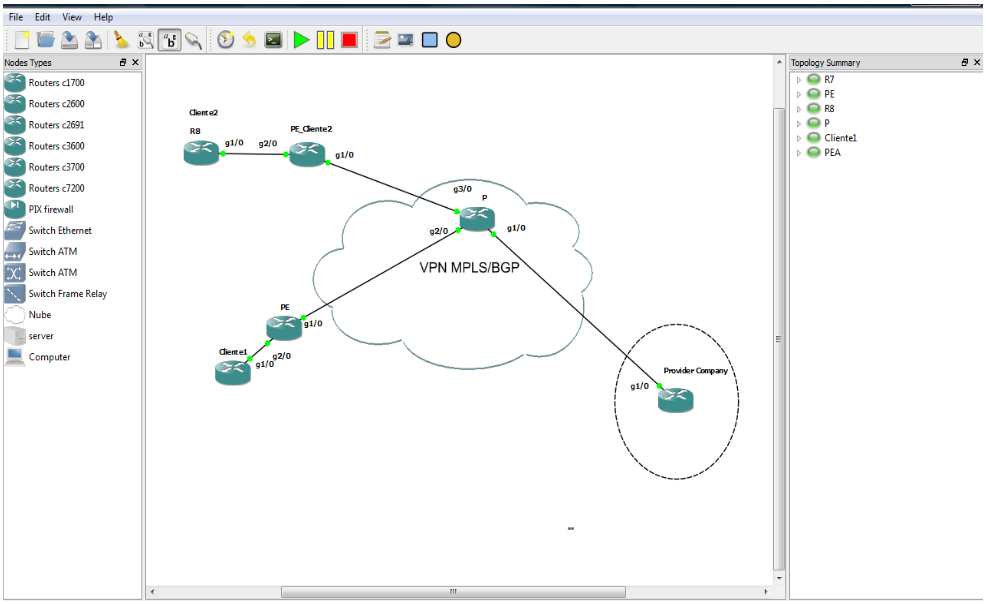


Fig a.6 Screen shot GNS3 scenario

The router Catalyst 7200 has been selected to make this emulation.
In the figure *fig. a.7* we can see a picture of this router.

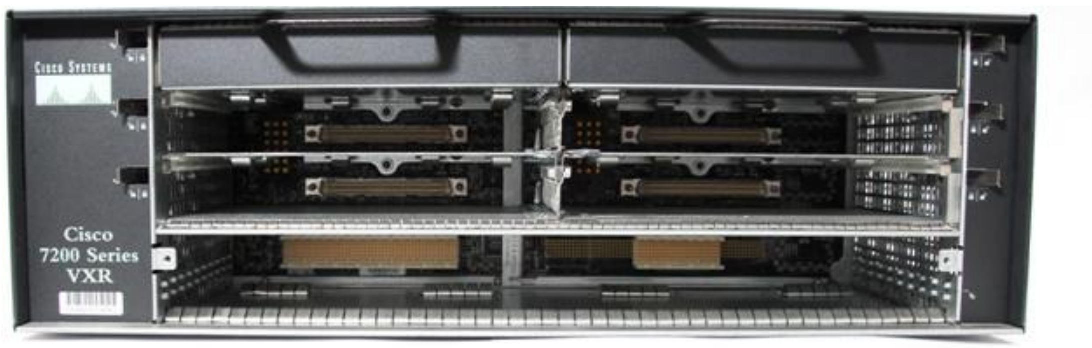


Fig a.7 Picture of Cisco 7200 series, which is used in the scenario.

TEST

The first point that we show is the “show ip route” of the principal routes, in this way we can observe the correctly work of IGP, BGP and MPLS protocols.

Router PE: Provider_Company

Provider_Company#Show ip route

Dynamips(3): PEA, Console port

```
Provider_Company#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     1.0.0.0/32 is subnetted, 1 subnets
C       1.1.1.1 is directly connected, Loopback0
     2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/2] via 10.10.10.2, 00:14:40, GigabitEthernet1/0
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/3] via 10.10.10.2, 00:14:40, GigabitEthernet1/0
     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/3] via 10.10.10.2, 00:14:40, GigabitEthernet1/0
     10.0.0.0/30 is subnetted, 3 subnets
O       10.10.10.8 [110/2] via 10.10.10.2, 00:14:40, GigabitEthernet1/0
C       10.10.10.0 is directly connected, GigabitEthernet1/0
O       10.10.10.4 [110/2] via 10.10.10.2, 00:14:40, GigabitEthernet1/0
Provider_Company#
```

In the figure we can see the routes IGP, in this case OSPF, learned by the router.

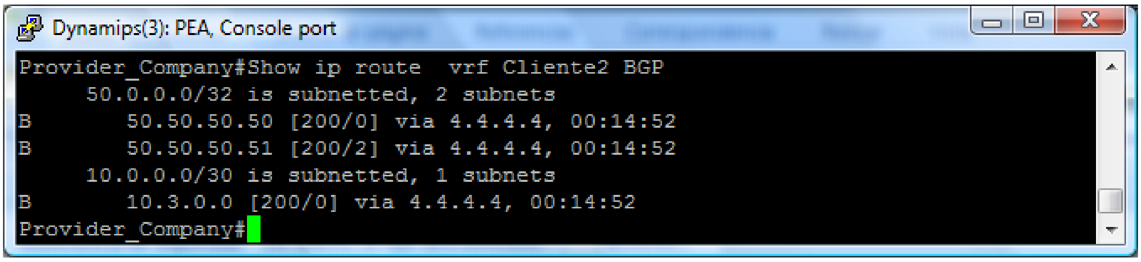
Provider_Company#Show ip route vrf Cliente1 BGP

Dynamips(3): PEA, Console port

```
Provider_Company#
Provider_Company#
Provider_Company#
Provider_Company#sh ip route vrf Cliente1 bgp
     201.201.201.0/32 is subnetted, 1 subnets
B       201.201.201.201 [200/0] via 3.3.3.3, 01:59:20
     101.0.0.0/32 is subnetted, 1 subnets
B       101.101.101.101 [200/2] via 3.3.3.3, 01:59:20
     10.0.0.0/24 is subnetted, 1 subnets
B       10.2.0.0 [200/0] via 3.3.3.3, 01:59:20
Provider_Company#
```

Now, we see the VRF *Cliente1* in the figure, also we can see that the VRF Cliente1 has learned the BGP routes of the other Router *Cliente1* VRF. We can note that the routes BGP are learned via Router 3.3.3.3, which is the PE of the *Cliente1.*

Provider_Company#Show ip route vrf Cliente2 BGP

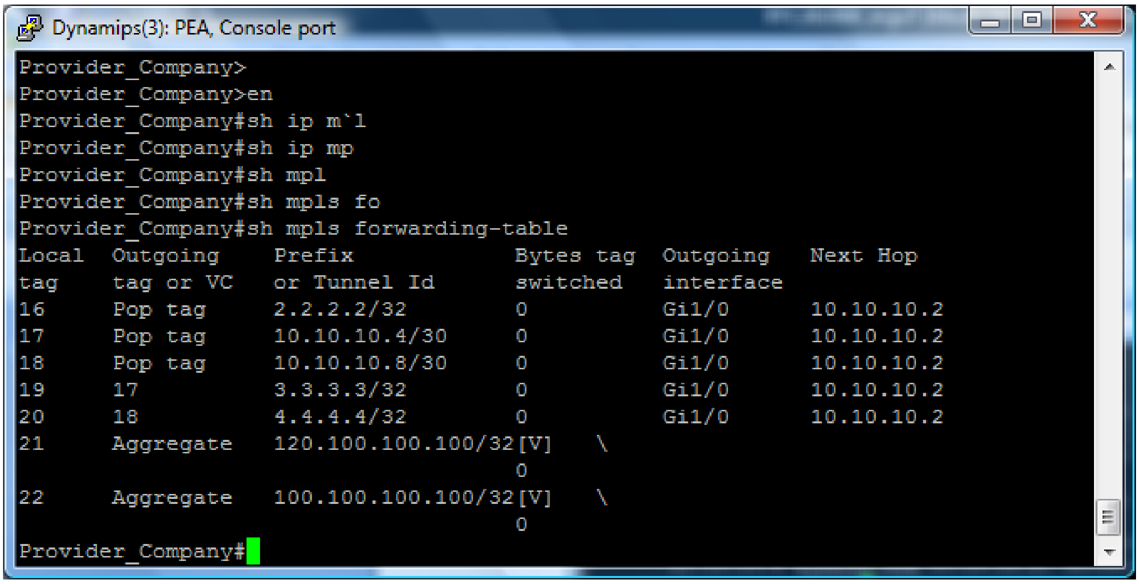



```
Provider_Company#Show ip route  vrf Cliente2 BGP
     50.0.0.0/32 is subnetted, 2 subnets
B       50.50.50.50 [200/0] via 4.4.4.4, 00:14:52
B       50.50.50.51 [200/2] via 4.4.4.4, 00:14:52
     10.0.0.0/30 is subnetted, 1 subnets
B       10.3.0.0 [200/0] via 4.4.4.4, 00:14:52
Provider_Company#
```

In this case we can observed how the Provider_Company learn the ip-route of VRF Cliente2 via router PE_Cliente2.

The other important point is to know if LDP has distributed the labels between the P and PE's.

Provider_Company#show mpls forwarding-table



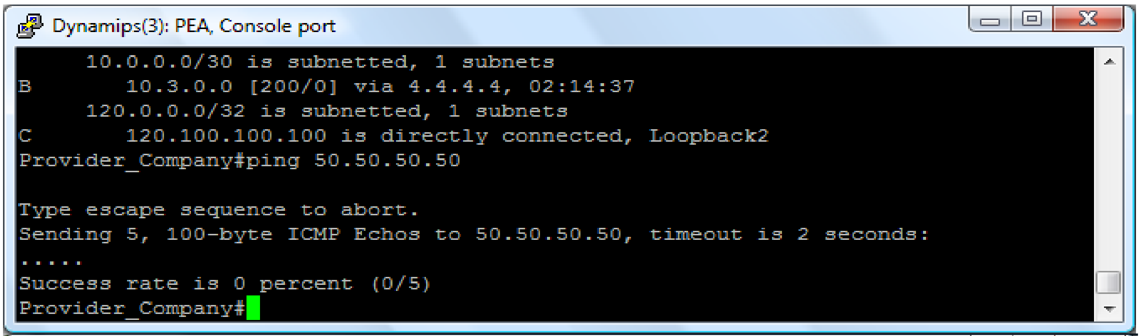

```
Provider_Company>
Provider_Company>en
Provider_Company#sh ip m`l
Provider_Company#sh ip mp
Provider_Company#sh mpl
Provider_Company#sh mpls fo
Provider_Company#sh mpls forwarding-table
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
16     Pop tag     2.2.2.2/32        0          Gi1/0      10.10.10.2
17     Pop tag     10.10.10.4/30     0          Gi1/0      10.10.10.2
18     Pop tag     10.10.10.8/30     0          Gi1/0      10.10.10.2
19     17          3.3.3.3/32        0          Gi1/0      10.10.10.2
20     18          4.4.4.4/32        0          Gi1/0      10.10.10.2
21     Aggregate   120.100.100.100/32[V]   \
                                     0
22     Aggregate   100.100.100.100/32[V]   \
                                     0
Provider_Company#
```

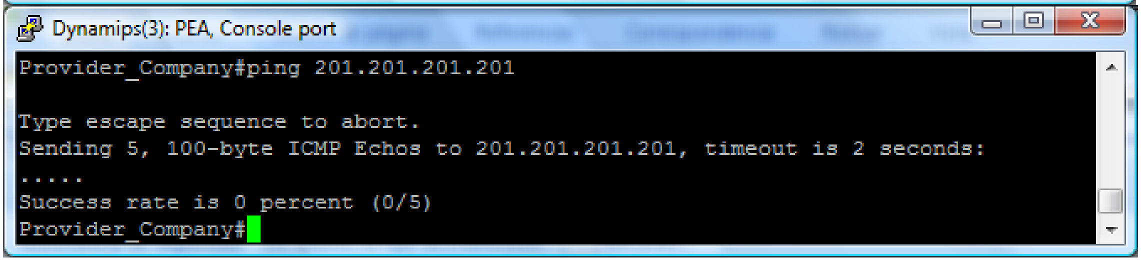
This command is used to check the MPLS forwarding table, which is the label switching equivalent of the IP routing table for standard IP routing. It contains inbound and outbound labels and descriptions of the packets.

In the figure we can see how the router POP (quit) or PUT labels, depending if the destination is in the same network of the router or not. Also we can see the option “Aggregate” when the destination is into a VPN. This “aggregation” is a tag option that has enough information to MP-BGP can obtain the destination VRF in the PE neighbor.

In the next figure we are going to try to do *pings* to other Customers.

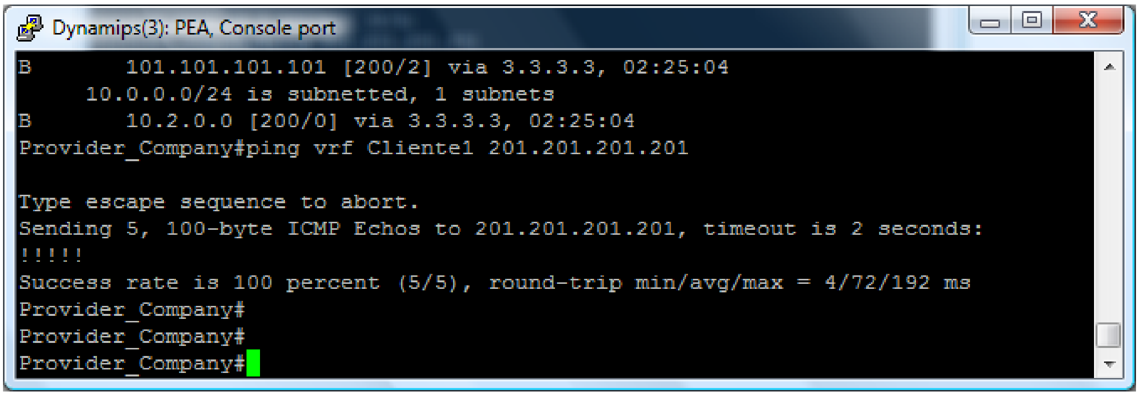
Provider_Company#ping 50.50.50.50
Provider_Company#ping 201.201.201.201





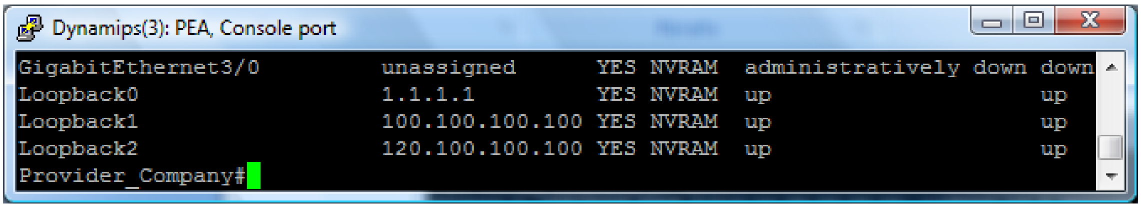
As we can see, it is not possible make *pings* from VRF default. There is not IP visibility between them, but If we make *pings* from VRF's the *ping* is successful.

Provider_Company#ping vrf Cliente1 201.201.201.201



With the purpose of simulate Customer IT services, we created different logical interfaces (loopback), in this way to assign each logical interface to Customer VRF corresponding.

Provider_Company# show ip interface brief

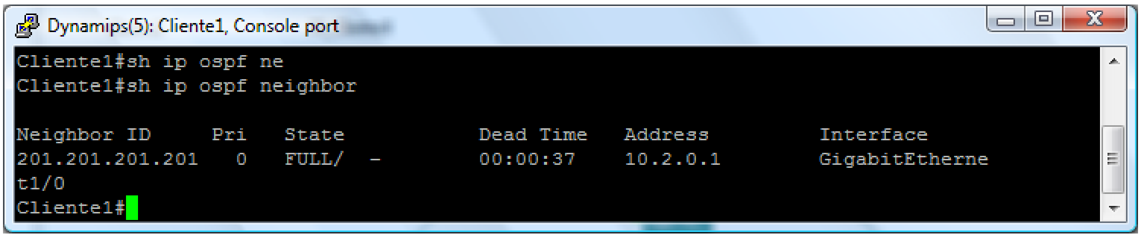


Loopback0 → it is necessary to route IGP between MPLS routes.
Loopback1→ it is associated at Cliente1 VRF.
Loopback2→ it is associated at Cliente2 VRF.

Router CE: Cliente1

The main function of this VPN/MPLS network is to get a secure communications between the customers and theirs IT services, which are located in the Provider Company infrastructure. So, it is very interesting to show the view from the Customer.
Firstly we show the IGP neighbours, in this case is the PE.

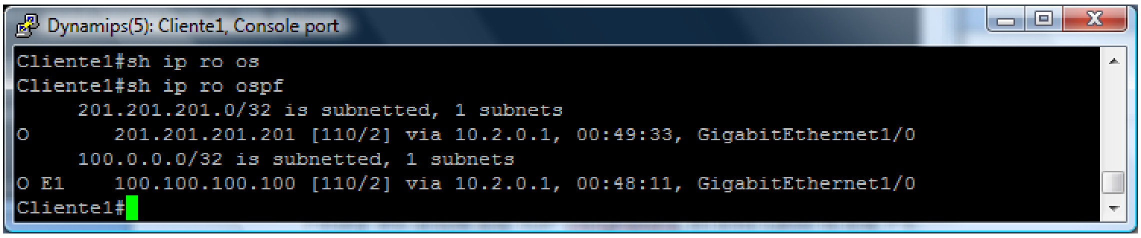
Cliente1#show ip ospf neighbor




```
Cliente1#sh ip ospf ne
Cliente1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
201.201.201.201   0   FULL/  -        00:00:37    10.2.0.1        GigabitEtherne
t1/0
Cliente1#
```

Now we go to show the IP routes, in this interface we need only to see the routes of the Customer services located in Provider_Company infrastructure. If we see other routes, this technology it is not enough to secure the IP communications.

Cliente1# Show ip routes ospf




```
Cliente1#sh ip ro os
Cliente1#sh ip ro ospf
     201.201.201.0/32 is subnetted, 1 subnets
O       201.201.201.201 [110/2] via 10.2.0.1, 00:49:33, GigabitEthernet1/0
     100.0.0.0/32 is subnetted, 1 subnets
O E1    100.100.100.100 [110/2] via 10.2.0.1, 00:48:11, GigabitEthernet1/0
Cliente1#
```

As set is showed, Customer (Cliente1) only has the routes of the adyancent PE, moreover theirs IT services in the Provider_Company. As we can see previously, in the figure *fig. a.8*, the PE redistributes in the Customer IGP the routes BGP learned of the Provider Customer. As conclusion, the Customer only has IP visibility with their network and IT services.

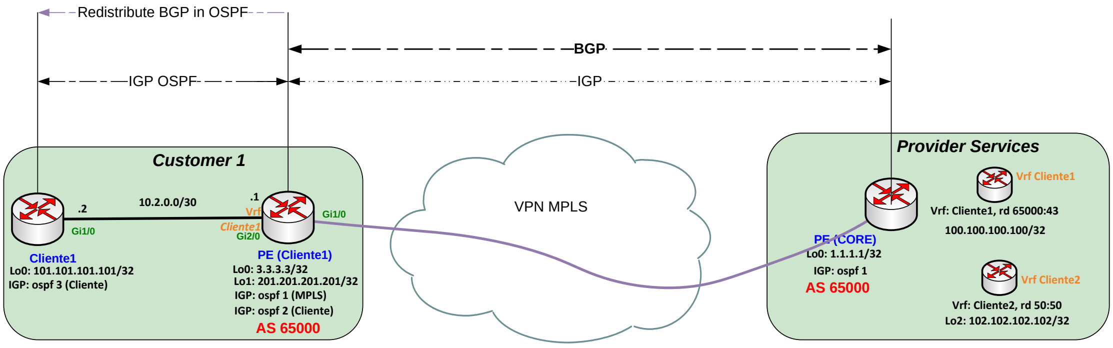


Fig a.8 Protocols between customer and company

Other interesting test is to know the ping between the IT services located in the Provider_Company and Customer.

Cliente1#ping 100.100.100.100

Dynamips(5): Cliente1, Console port

```
Cliente1#ping 100.100.100.100

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 100.100.100.100, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/102/272 ms
Cliente1#
```

Router CE: Cliente2

Cliente2#show the IP routes

Dynamips(1): R8, Console port

```
Cliente2#sh ip ro os
     50.0.0.0/32 is subnetted, 2 subnets
O       50.50.50.50 [110/2] via 10.3.0.1, 02:00:54, GigabitEthernet1/0
     120.0.0.0/32 is subnetted, 1 subnets
O E1    120.100.100.100 [110/2] via 10.3.0.1, 01:59:32, GigabitEthernet1/0
Cliente2#
Cliente2#
```

Carrier Support Scenario based on Carrier VPN MPLS

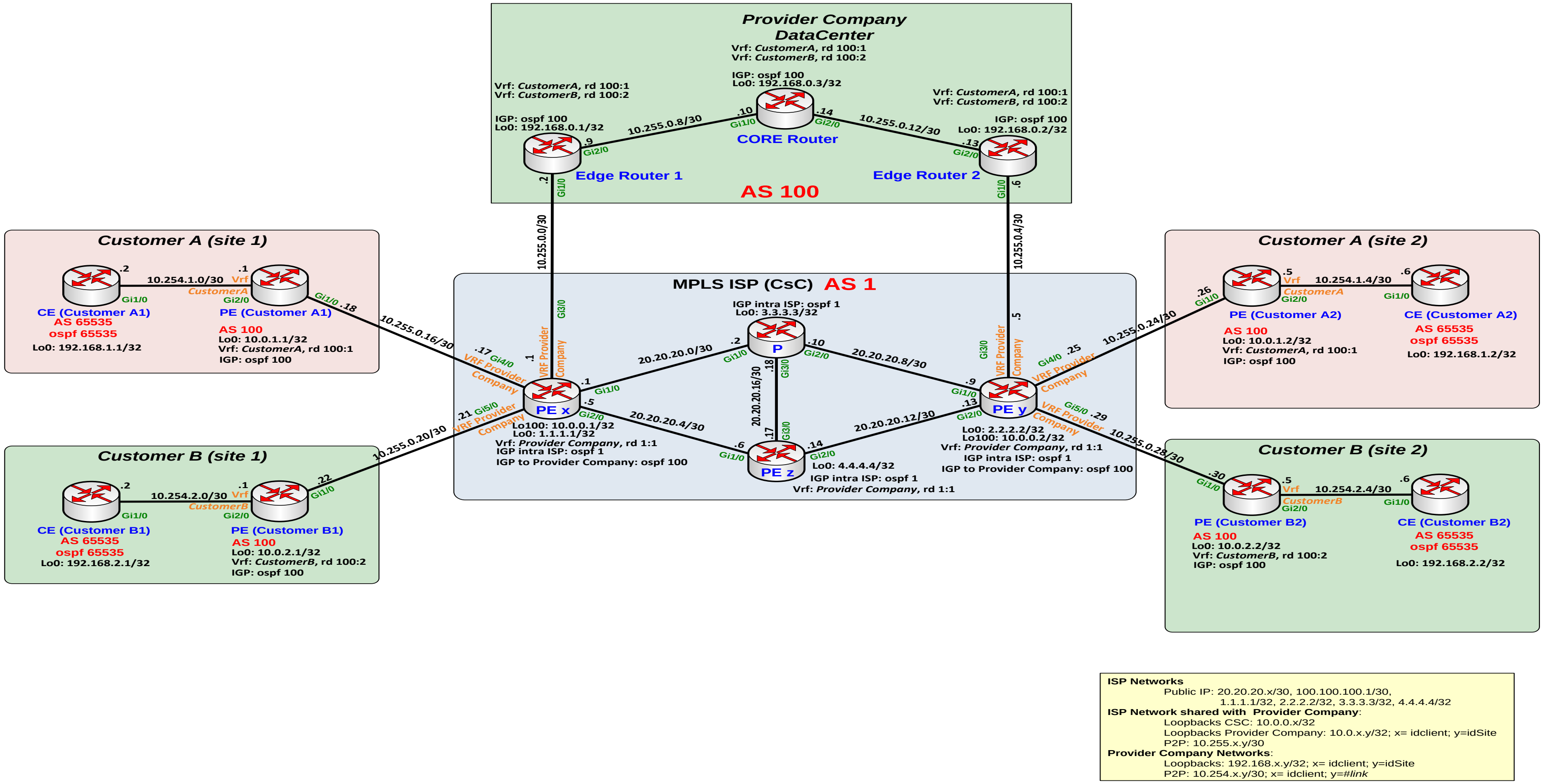


Fig a.9 BPG and IGP protocols deployment in the MPLS/VPN network proposed.

The GNS3 design is the next:

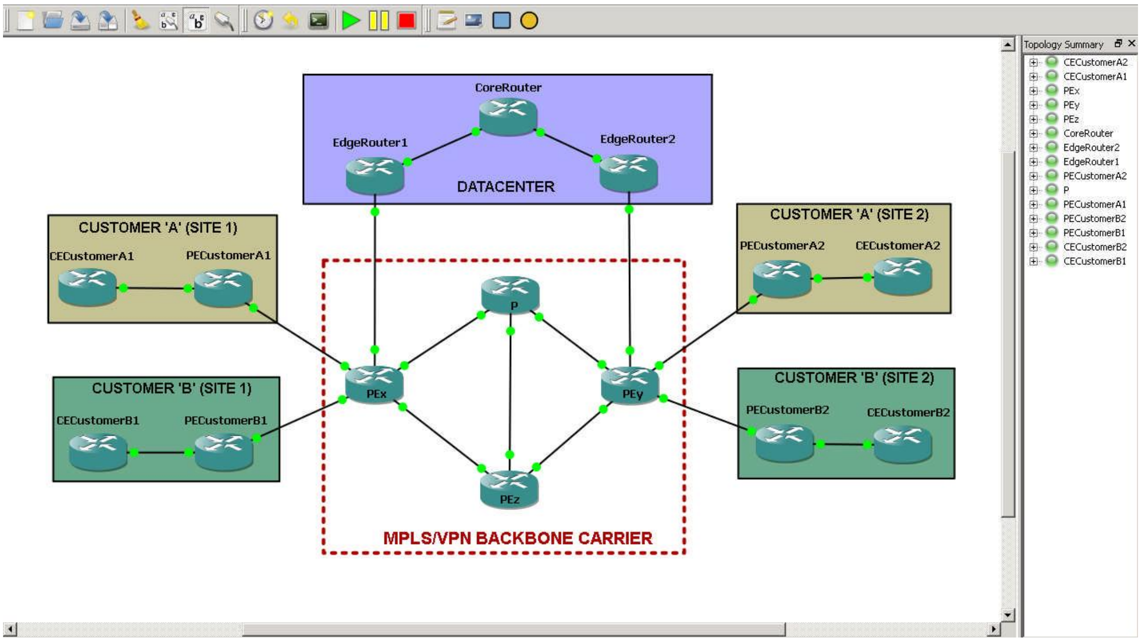


Fig a.10 Screen shot GNS3 scenario

Before to show the screenshots of the devices, it is important to stress that the IT Customer services in the *Datacenter* are represented with the follow Loopbacks:

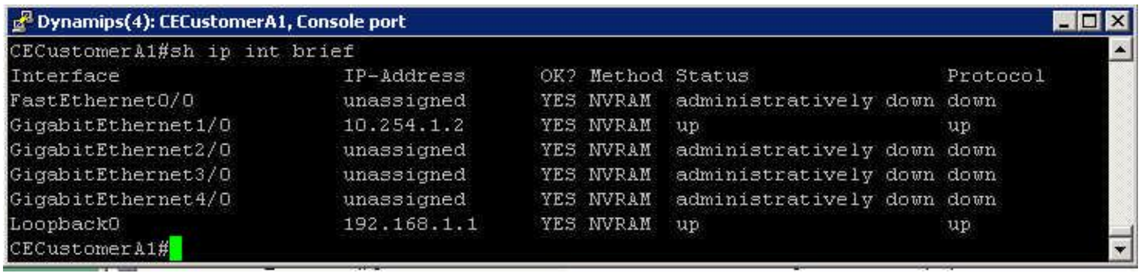
IP 172.16.1.1→ Customer A services
IP 172.16.2.1→ Customer B services

```
interface Loopback2000
 description *** CUSTOMER A NETWORK ***
 ip vrf forwarding CUSTOMERA
 ip address 172.16.1.1 255.255.255.255
!
interface Loopback2001
 description *** CUSTOMER B NETWORK ***
 ip vrf forwarding CUSTOMERB
 ip address 172.16.2.1 255.255.255.255
```

In the next figures, we are going to make different test between the Customer A1 and the all elements of the network, thus we can obtain the sufficient information to demonstrate that this scenario is valid to offer IT services over WAN connections.

In this screenshot we can see the IP assigned in the logical interfaces.

CECustomerA1#sh ip interface brief

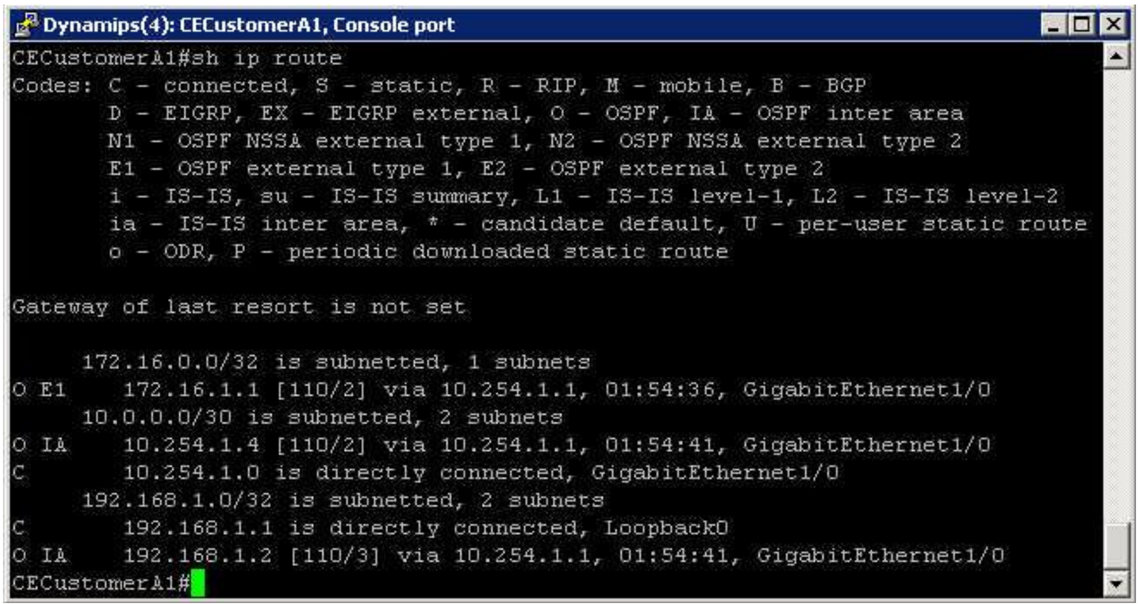


Dynamips(4): CECustomerA1, Console port

```
CECustomerA1#sh ip int brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES NVRAM  administratively down down
GigabitEthernet1/0     10.254.1.2      YES NVRAM  up                    up
GigabitEthernet2/0     unassigned      YES NVRAM  administratively down down
GigabitEthernet3/0     unassigned      YES NVRAM  administratively down down
GigabitEthernet4/0     unassigned      YES NVRAM  administratively down down
Loopback0              192.168.1.1     YES NVRAM  up                    up
CECustomerA1#
```

CECustomerA1# Show ip route

With this command we can see IP visibility of the CECustomerA1. This screenshot is important due to allows us verify that the logical visibility of the customer is our *Datacenter* and their other site.



Dynamips(4): CECustomerA1, Console port

```
CECustomerA1#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/32 is subnetted, 1 subnets
O E1    172.16.1.1 [110/2] via 10.254.1.1, 01:54:36, GigabitEthernet1/0
     10.0.0.0/30 is subnetted, 2 subnets
O IA    10.254.1.4 [110/2] via 10.254.1.1, 01:54:41, GigabitEthernet1/0
C       10.254.1.0 is directly connected, GigabitEthernet1/0
     192.168.1.0/32 is subnetted, 2 subnets
C       192.168.1.1 is directly connected, Loopback0
O IA    192.168.1.2 [110/3] via 10.254.1.1, 01:54:41, GigabitEthernet1/0
CECustomerA1#
```

As we can see in the last screenshot, the ip visibility of the Customer A is their IT services in the *Datacenter* (172.16.1.1) and the networks of the other Customer A site (192.168.1.2). These IPs are distributed to CustomerAsite1 by PE_Customer A1. The figure a.11 summarizes the IP visibility of the Customer A1.

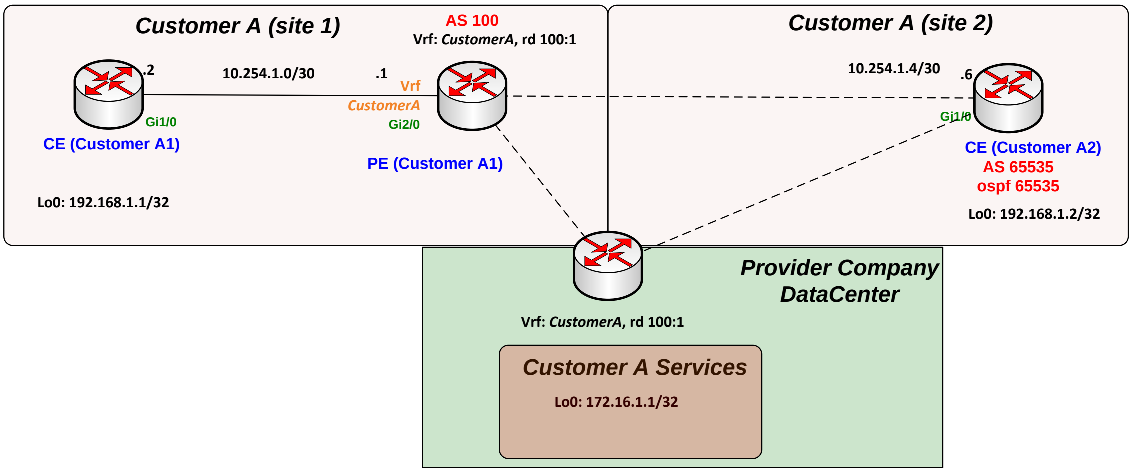
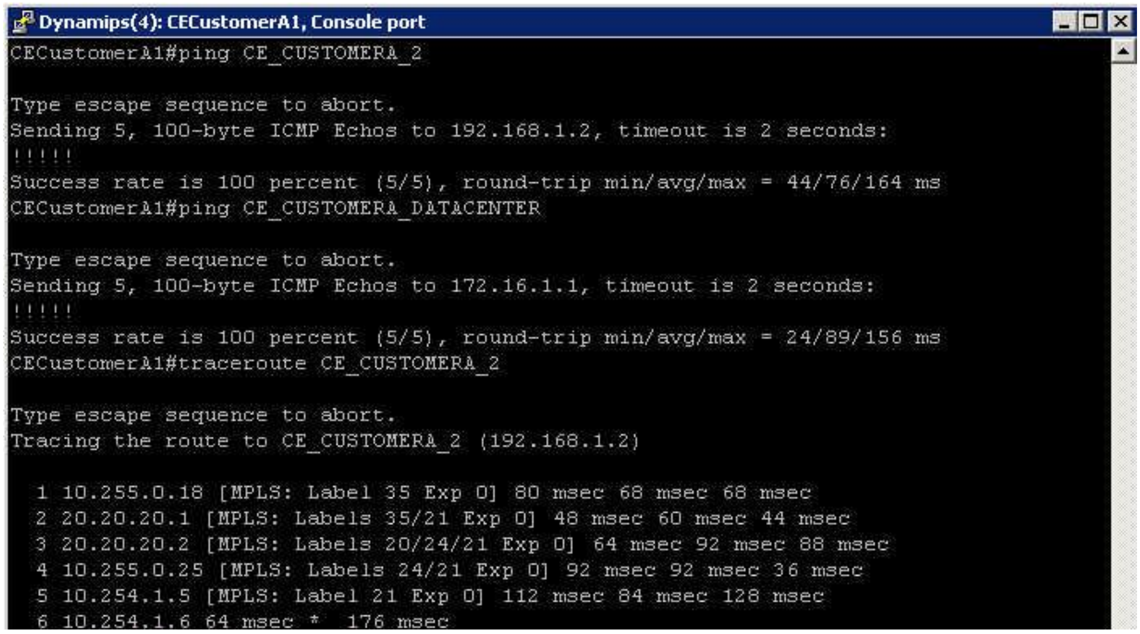


Fig a.11 Logical visibility of the CustomerA

As we can see in the figure fig a.11 the goal of the design is completed, the customer A has direct visibility between their IT services in Datacenter and their sites.
We make pings between the Customer A1 and the rest of their networks.

CEcustomerA1#ping CE_CUSTOMERA_2
CEcustomerA1#ping CE_CUSTOMERA_DATACENTER




```
CECustomerA1#ping CE_CUSTOMERA_2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 44/76/164 ms
CECustomerA1#ping CE_CUSTOMERA_DATACENTER

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 24/89/156 ms
CECustomerA1#traceroute CE_CUSTOMERA_2

Type escape sequence to abort.
Tracing the route to CE_CUSTOMERA_2 (192.168.1.2)

  1 10.255.0.18 [MPLS: Label 35 Exp 0] 80 msec 68 msec 68 msec
  2 20.20.20.1 [MPLS: Labels 35/21 Exp 0] 48 msec 60 msec 44 msec
  3 20.20.20.2 [MPLS: Labels 20/24/21 Exp 0] 64 msec 92 msec 88 msec
  4 10.255.0.25 [MPLS: Labels 24/21 Exp 0] 92 msec 92 msec 36 msec
  5 10.254.1.5 [MPLS: Label 21 Exp 0] 112 msec 84 msec 128 msec
  6 10.254.1.6 64 msec *  176 msec
```

In the last screenshot we can see how the customer A1 can make pings between their sites and IT services located at Datacenter.
We are going to try making pings to others Customers

CEcustomerA1#ping CE_CUSTOMERB_1
CEcustomerA1#ping CE_CUSTOMERB_2
CEcustomerA1#ping CE_CUSTOMERB_DATACENTER

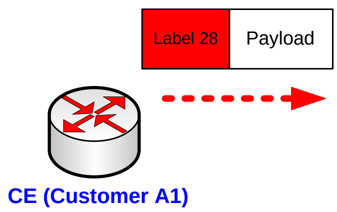
```
Dynamips(4): CECustomerA1, Console port
CECustomerA1#ping CE_CUSTOMERB_1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.1, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
CECustomerA1#ping CE_CUSTOMERB_2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.2.2, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
CECustomerA1#ping CE_CUSTOMERB_DATACENTER

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.2.1, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
CECustomerA1#
```

Now, we are going to see the tracertroute (see the way of the information over network) tracerts between the Custome rA and IT services in Datacenter are successful. Moreover, we can see the MPLS labels between them.

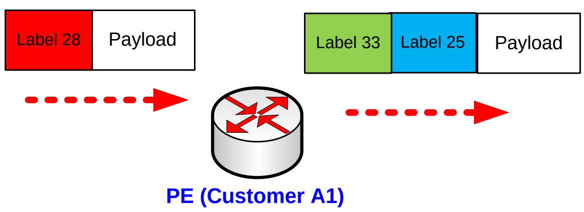
CEcustomerA1#tracertroute CE_CUSTOMERA_2
CEcustomerA1#tracertroute CE_CUSTOMERA_DATACENTER

```
CECustomerA1#traceroute CE_CUSTOMERA_DATACENTER

Type escape sequence to abort.
Tracing the route to CE_CUSTOMERA_DATACENTER (172.16.1.1)

  1 10.255.0.18 [MPLS: Label 28 Exp 0] 100 msec 48 msec 28 msec
  2 10.255.0.1 [MPLS: Labels 33/25 Exp 0] 28 msec 28 msec 32 msec
  3 10.255.0.2 [MPLS: Labels 23/25 Exp 0] 28 msec 40 msec 32 msec
  4 CE_CUSTOMERA_DATACENTER (172.16.1.1) [MPLS: Label 25 Exp 0] 36 msec *  140 msec
CECustomerA1#
```

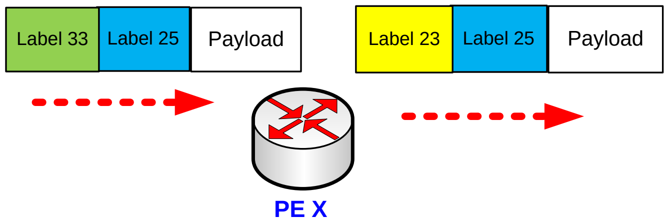
10.255.0.18 MPLS: label 28 (PUSH)



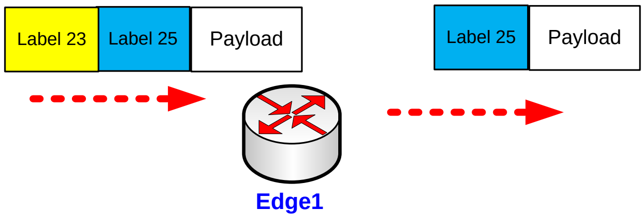
10.255.0.1 MPLS: Labels 33/25 (PUSH and POP)



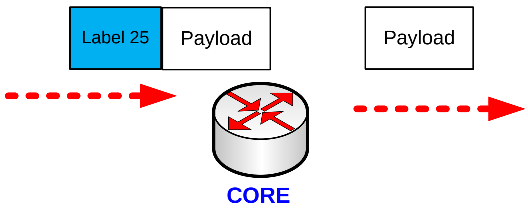
10.255.0.2 MPLS: Labels 23/25 (SWAP)



10.255.0.2 MPLS: Labels 25 (POP)



10.255.0.10 MPLS: Labels 25 (POP)



The figure a.12 summarizes the MPLS process.

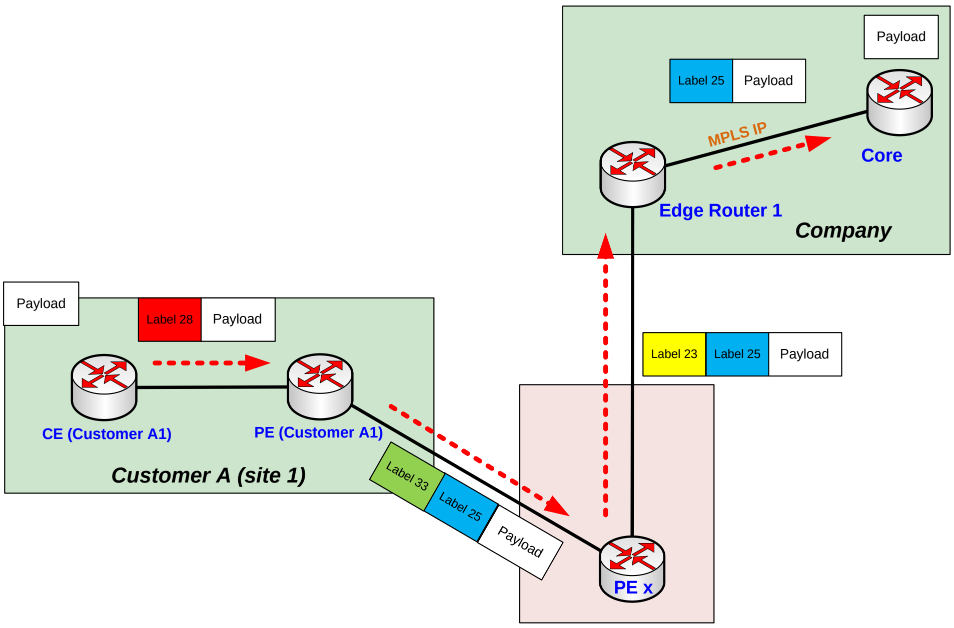
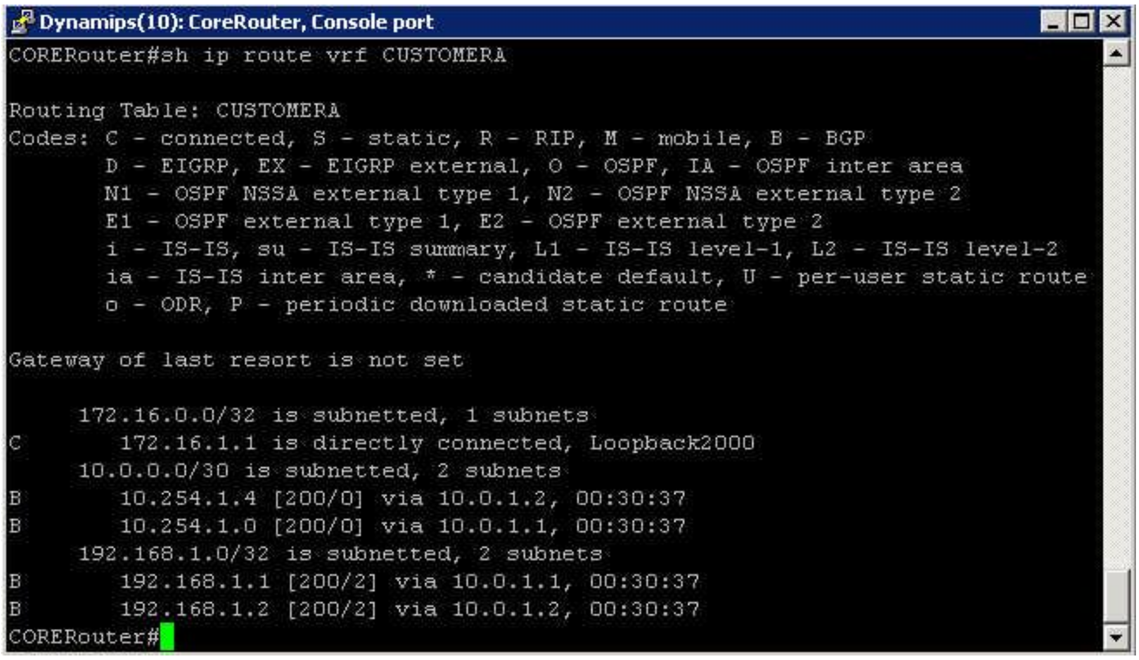


Fig a.12 MPLS label process

In the same way, we can see the IP routes of the *Datacenter* respect to Customer A.

CORERouter#Show ip route vrf CUSTOMERA



Like we can see in the next picture, CORERouter only can see the IP's of customer A if it makes respect VRF Customer A

- 10.254.1.4→ Customer A site 2 network
- 10.254.1.0→ Customer A site 1 network
- 192.168.1.1→ Customer A site 1 core
- 192.168.1.2 → CustomerA site 2 core

Also, it is very interesting to see how PE_CustomerA1 learns all IP routes of VRF Company domain. It is important to note that this router will be controlled by Company. In the figure a.13 e can see the mesh between the Edge Company Routers and all PE Customer, in this way the company can controller own network. We remember that this network belongs at AS 100 of the figure a.8. Try to found a ISP route (20.x.x.x.) in the IP route of the PE_Customer is the best way to verify this.

PE_CustomerA#show ip route

Dynamips(5): PECustomerA1, Console port

```
PECustomerA1#sh ip ro
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 14 subnets, 2 masks
O IA    10.0.0.2/32 [110/2] via 10.255.0.17, 01:06:07, GigabitEthernet1/0
O       10.0.2.1/32 [110/3] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
O IA    10.0.1.2/32 [110/3] via 10.255.0.17, 01:06:07, GigabitEthernet1/0
O IA    10.0.2.2/32 [110/3] via 10.255.0.17, 01:06:07, GigabitEthernet1/0
C       10.0.1.1/32 is directly connected, Loopback0
O       10.0.0.1/32 [110/2] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
O       10.255.0.20/30 [110/2] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
C       10.255.0.16/30 is directly connected, GigabitEthernet1/0
O IA    10.255.0.28/30 [110/2] via 10.255.0.17, 01:06:07, GigabitEthernet1/0
O IA    10.255.0.24/30 [110/2] via 10.255.0.17, 01:06:07, GigabitEthernet1/0
O       10.255.0.4/30 [110/5] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
O       10.255.0.0/30 [110/2] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
O       10.255.0.12/30 [110/4] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
O       10.255.0.8/30 [110/3] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
     192.168.0.0/32 is subnetted, 3 subnets
O       192.168.0.1 [110/3] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
O       192.168.0.2 [110/5] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
O       192.168.0.3 [110/4] via 10.255.0.17, 01:07:03, GigabitEthernet1/0
PECustomerA1#
```

As we can see there are not ISP routes and so we demonstrate that the ISP network is transparent for us (Company). To improve the understanding of the routers showed we make a figure a.13 that summarizes the IP visibility of the PE_CustomerA1.

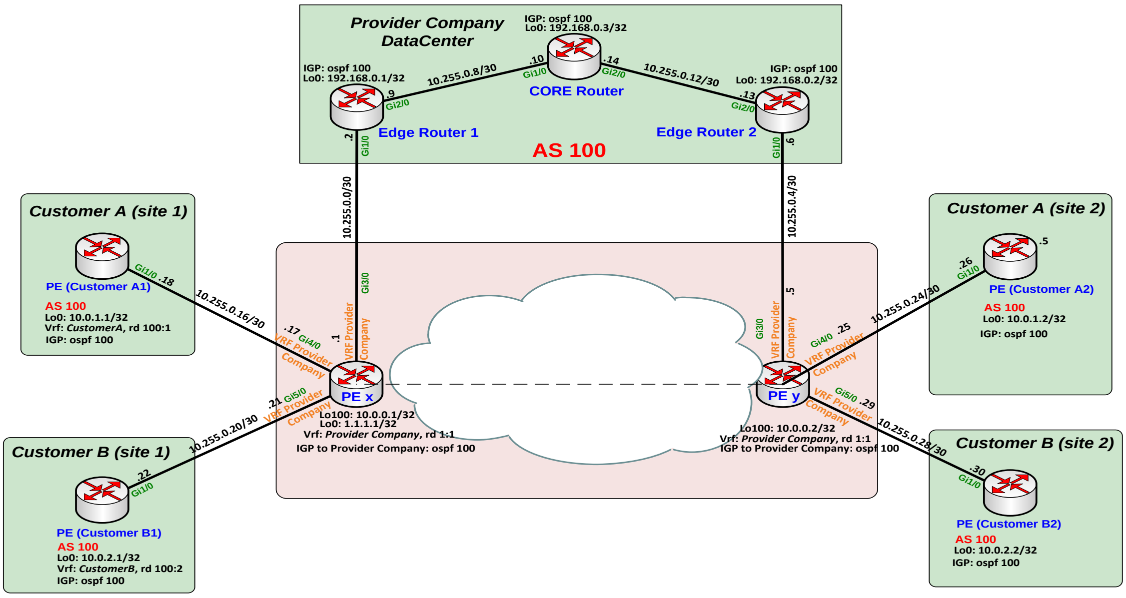


Fig a.13 IP visibility of the PE_CustomerA1.

We are going to summarize in groups the rest of screenshot made in the scenario.

Core Router

Show interface description

Dynamips(10): CoreRouter, Console port

```
COREROuter#sh int desc
Interface                      Status         Protocol Description
Fa0/0                          admin down     down
Gi1/0                          up             up       *** LINK to Edge Router 1 COMPANY ***
Gi2/0                          up             up       *** LINK to Edge Router 2 COMPANY ***
Gi3/0                          admin down     down
Gi4/0                          admin down     down
Lo0                            up             up       *** MANAGEMENT PURPOSES ***
Lo2000                         up             up       *** CUSTOMER A NETWORK ***
Lo2001                         up             up       *** CUSTOMER B NETWORK ***
COREROuter#
```

Show ip interface brief

Dynamips(10): CoreRouter, Console port

```
COREROuter#sh ip int brief
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            unassigned      YES unset  administratively down down
GigabitEthernet1/0         10.255.0.10     YES manual up                    up
GigabitEthernet2/0         10.255.0.14     YES manual up                    up
GigabitEthernet3/0         unassigned      YES unset  administratively down down
GigabitEthernet4/0         unassigned      YES unset  administratively down down
Loopback0                  192.168.0.3     YES manual up                    up
Loopback2000               172.16.1.1      YES manual up                    up
Loopback2001               172.16.2.1      YES manual up                    up
COREROuter#
```

Sh ip bgp summary

Dynamips(10): CoreRouter, Console port

```
COREROuter#sh ip bgp summary
BGP router identifier 192.168.0.3, local AS number 100
BGP table version is 1, main routing table version 1

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.0.1     4   100    4355    8648        1    0    0 10:43:17        0
192.168.0.2     4   100    3660    7270        1    0    0 10:04:40        0
COREROuter#
```

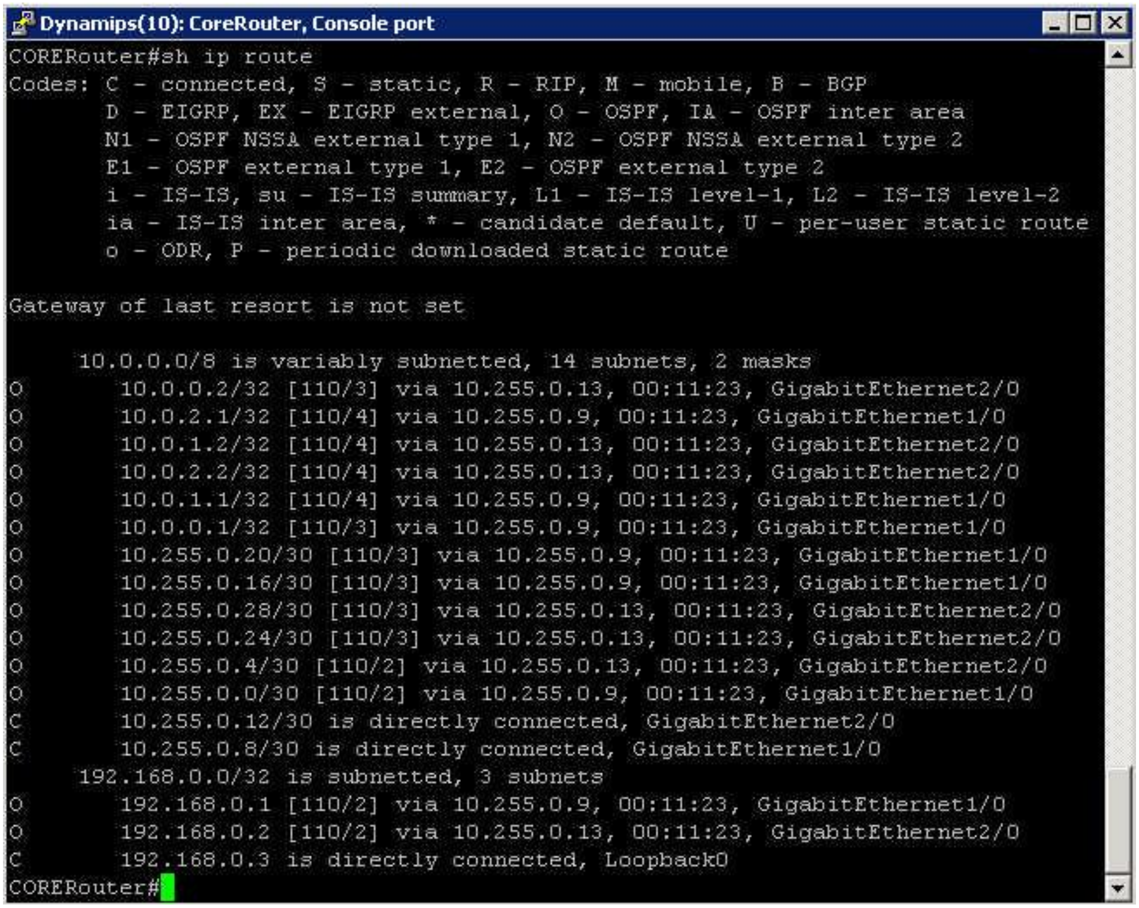
Show ip bgp vpnv4 all

```
Dynamips(10): CoreRouter, Console port
COREROuter#sh ip bgp vpnv4 all
BGP table version is 66, local router ID is 192.168.0.3
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop            Metric LocPrf Weight Path
Route Distinguisher: 100:1 (default for vrf CUSTOMERA)
*>i10.254.1.0/30    10.0.1.1                 0    100      0 ?
* i                 10.0.1.1                 0    100      0 ?
*>i10.254.1.4/30    10.0.1.2                 0    100      0 ?
* i                 10.0.1.2                 0    100      0 ?
*> 172.16.1.1/32    0.0.0.0                  0         32768 ?
*>i192.168.1.1/32   10.0.1.1                 2    100      0 ?
* i                 10.0.1.1                 2    100      0 ?
*>i192.168.1.2/32   10.0.1.2                 2    100      0 ?
* i                 10.0.1.2                 2    100      0 ?
Route Distinguisher: 100:2 (default for vrf CUSTOMERB)
* i10.254.2.0/30    10.0.2.1                 0    100      0 ?
*>i                 10.0.2.1                 0    100      0 ?
* i10.254.2.4/30    10.0.2.2                 0    100      0 ?
*>i                 10.0.2.2                 0    100      0 ?
*> 172.16.2.1/32    0.0.0.0                  0         32768 ?
* i192.168.2.1/32   10.0.2.1                 2    100      0 ?
*>i                 10.0.2.1                 2    100      0 ?
* i192.168.2.2/32   10.0.2.2                 2    100      0 ?
*>i                 10.0.2.2                 2    100      0 ?
COREROuter#
```

Sh ip ospf neigbor

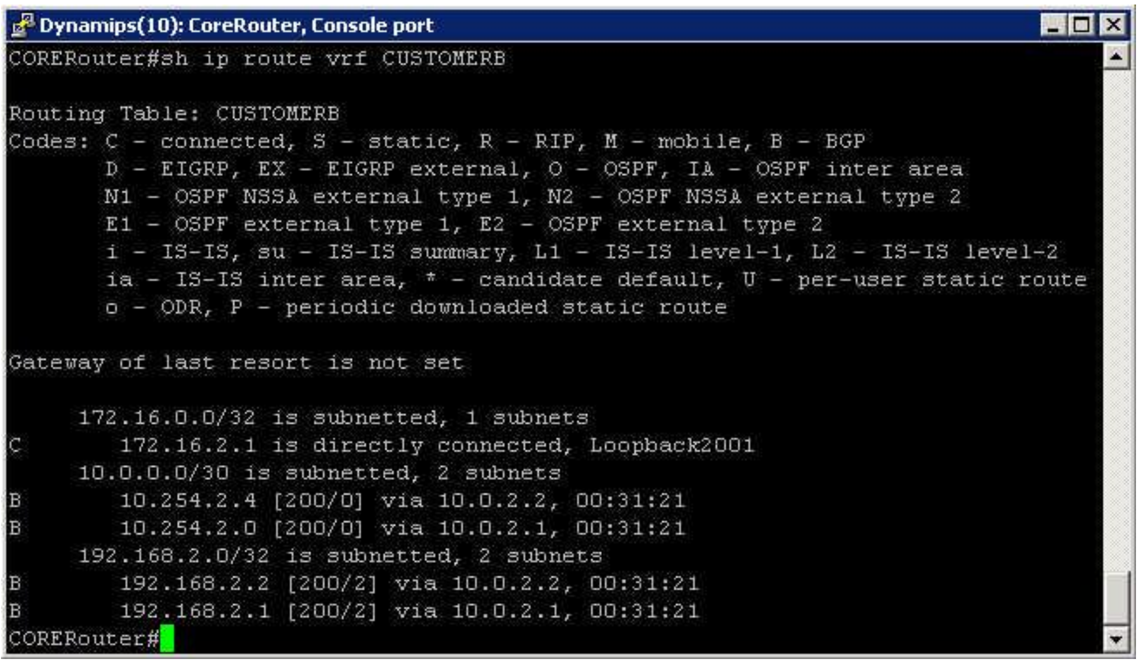
```
Dynamips(10): CoreRouter, Console port
COREROuter#sh ip ospf 100 neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
EDGE_2            1   FULL/BDR        00:00:30    10.255.0.13     GigabitEthernet2/0
EDGE_1            1   FULL/DR         00:00:32    10.255.0.9      GigabitEthernet1/0
COREROuter#
```

Show ip route



Dynamips(10): CoreRouter, Console port

```
CORERouter#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 14 subnets, 2 masks
O       10.0.0.2/32 [110/3] via 10.255.0.13, 00:11:23, GigabitEthernet2/0
O       10.0.2.1/32 [110/4] via 10.255.0.9, 00:11:23, GigabitEthernet1/0
O       10.0.1.2/32 [110/4] via 10.255.0.13, 00:11:23, GigabitEthernet2/0
O       10.0.2.2/32 [110/4] via 10.255.0.13, 00:11:23, GigabitEthernet2/0
O       10.0.1.1/32 [110/4] via 10.255.0.9, 00:11:23, GigabitEthernet1/0
O       10.0.0.1/32 [110/3] via 10.255.0.9, 00:11:23, GigabitEthernet1/0
O       10.255.0.20/30 [110/3] via 10.255.0.9, 00:11:23, GigabitEthernet1/0
O       10.255.0.16/30 [110/3] via 10.255.0.9, 00:11:23, GigabitEthernet1/0
O       10.255.0.28/30 [110/3] via 10.255.0.13, 00:11:23, GigabitEthernet2/0
O       10.255.0.24/30 [110/3] via 10.255.0.13, 00:11:23, GigabitEthernet2/0
O       10.255.0.4/30 [110/2] via 10.255.0.13, 00:11:23, GigabitEthernet2/0
O       10.255.0.0/30 [110/2] via 10.255.0.9, 00:11:23, GigabitEthernet1/0
C       10.255.0.12/30 is directly connected, GigabitEthernet2/0
C       10.255.0.8/30 is directly connected, GigabitEthernet1/0
     192.168.0.0/32 is subnetted, 3 subnets
O       192.168.0.1 [110/2] via 10.255.0.9, 00:11:23, GigabitEthernet1/0
O       192.168.0.2 [110/2] via 10.255.0.13, 00:11:23, GigabitEthernet2/0
C       192.168.0.3 is directly connected, Loopback0
CORERouter#
```



Dynamips(10): CoreRouter, Console port

```
CORERouter#sh ip route vrf CUSTOMERB

Routing Table: CUSTOMERB
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/32 is subnetted, 1 subnets
C       172.16.2.1 is directly connected, Loopback2001
     10.0.0.0/30 is subnetted, 2 subnets
B       10.254.2.4 [200/0] via 10.0.2.2, 00:31:21
B       10.254.2.0 [200/0] via 10.0.2.1, 00:31:21
     192.168.2.0/32 is subnetted, 2 subnets
B       192.168.2.2 [200/2] via 10.0.2.2, 00:31:21
B       192.168.2.1 [200/2] via 10.0.2.1, 00:31:21
CORERouter#
```

Show ip vrf

```
Dynamips(10): CoreRouter, Console port
COREROuter#sh ip vrf
  Name                             Default RD          Interfaces
  CUSTOMERA                        100:1               Lo2000
  CUSTOMERB                        100:2               Lo2001
COREROuter#
```

Show ip mpls forwarding-table

```
Dynamips(10): CoreRouter, Console port
COREROuter#sh mpls forwarding-table
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
16     Pop tag     10.255.0.0/30     0          Gi1/0      10.255.0.9
17     16          10.0.0.1/32       0          Gi1/0      10.255.0.9
18     17          10.255.0.20/30    0          Gi1/0      10.255.0.9
19     18          10.255.0.16/30    0          Gi1/0      10.255.0.9
20     Pop tag     192.168.0.1/32    104883     Gi1/0      10.255.0.9
21     19          10.0.1.1/32       269801     Gi1/0      10.255.0.9
22     20          10.0.2.1/32       261064     Gi1/0      10.255.0.9
23     25          10.0.0.2/32       0          Gi2/0      10.255.0.13
24     26          10.0.1.2/32       36038      Gi2/0      10.255.0.13
25     Aggregate   172.16.1.1/32[V]  12036
26     27          10.0.2.2/32       18957      Gi2/0      10.255.0.13
27     Pop tag     10.255.0.4/30     0          Gi2/0      10.255.0.13
28     Pop tag     192.168.0.2/32    2397162    Gi2/0      10.255.0.13
29     28          10.255.0.24/30    0          Gi2/0      10.255.0.13
30     29          10.255.0.28/30    0          Gi2/0      10.255.0.13
32     Aggregate   172.16.2.1/32[V]  1040
COREROuter#
```

PEx

Show ip bgp summary

```
Dynamips(6): PEx, Console port
PEx#sh ip bgp summary
BGP router identifier 1.1.1.1, local AS number 1
BGP table version is 1, main routing table version 1

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2.2.2.2         4     1     197     199        1    0    0 00:15:44        0
4.4.4.4         4     1     198     205        1    0    0 00:16:04        0
PEx#
```

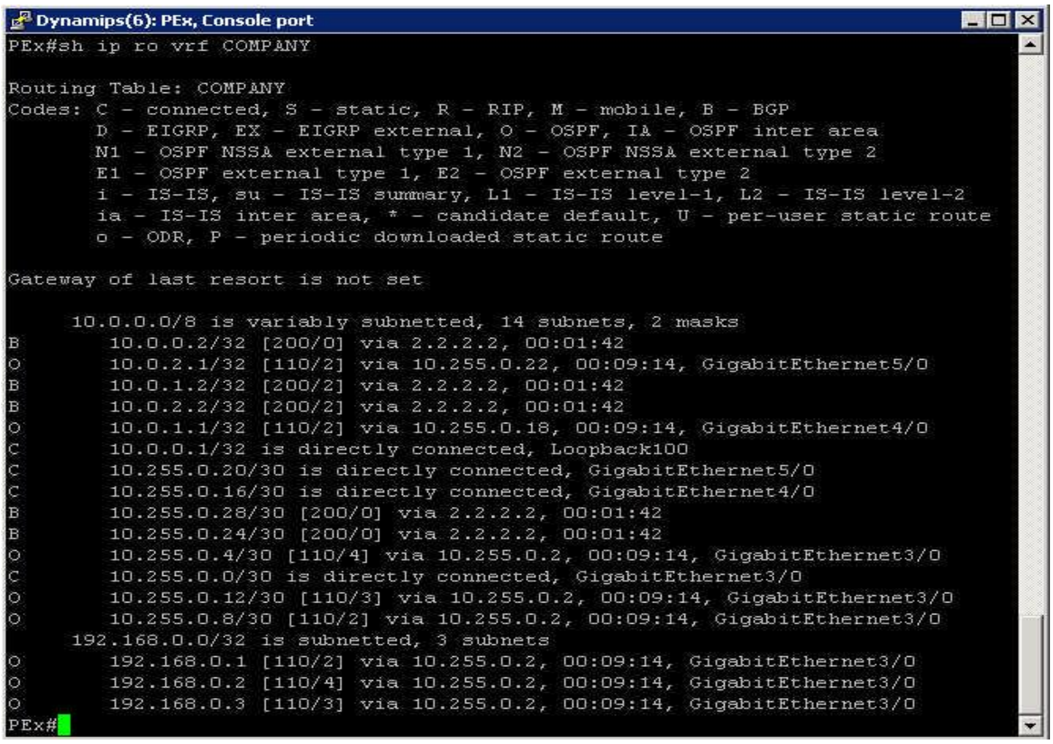
Show ip ospf neighbor

```
Dynamips(6): PEx, Console port
PEx#sh ip ospf 100 neighbor

Neighbor ID      Pri   State           Dead Time   Address         Interface
PECUSTOMERB1_Lo    1   FULL/DR         00:00:32    10.255.0.22     GigabitEthernet5/0
PECUSTOMERA1_Lo    1   FULL/DR         00:00:35    10.255.0.18     GigabitEthernet4/0
Edge1              1   FULL/DR         00:00:38    10.255.0.2      GigabitEthernet3/0
PEx#sh ip ospf 1 neighbor

Neighbor ID      Pri   State           Dead Time   Address         Interface
PEz                1   FULL/DR         00:00:38    20.20.20.6      GigabitEthernet2/0
P                  1   FULL/DR         00:00:34    20.20.20.2      GigabitEthernet1/0
PEx#
```

Show ip route

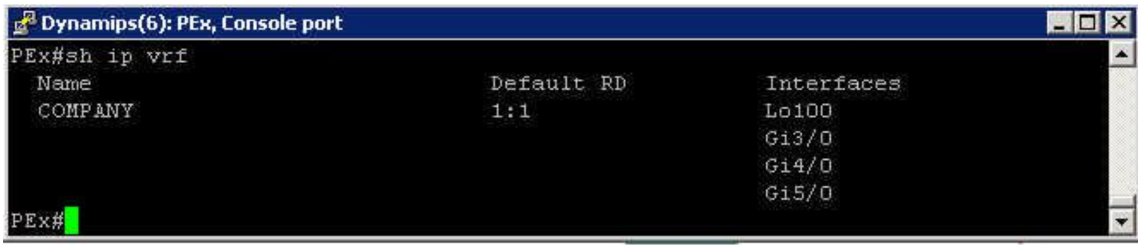
```
Dynamips(6): PEx, Console port
PEx#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     1.0.0.0/32 is subnetted, 1 subnets
C       1.1.1.1 is directly connected, Loopback0
     2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/3] via 20.20.20.2, 04:45:19, GigabitEthernet1/0
     3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/2] via 20.20.20.2, 04:45:19, GigabitEthernet1/0
     4.0.0.0/32 is subnetted, 1 subnets
O       4.4.4.4 [110/2] via 20.20.20.6, 04:45:19, GigabitEthernet2/0
     20.0.0.0/30 is subnetted, 5 subnets
O       20.20.20.16 [110/2] via 20.20.20.6, 04:45:19, GigabitEthernet2/0
                    [110/2] via 20.20.20.2, 04:45:19, GigabitEthernet1/0
C       20.20.20.4 is directly connected, GigabitEthernet2/0
C       20.20.20.0 is directly connected, GigabitEthernet1/0

PEx#
```

Show IP route vrf Company



```
Dynamips(6): PEx, Console port
PEx#sh ip ro vrf COMPANY

Routing Table: COMPANY
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 14 subnets, 2 masks
B       10.0.0.2/32 [200/0] via 2.2.2.2, 00:01:42
O       10.0.2.1/32 [110/2] via 10.255.0.22, 00:09:14, GigabitEthernet5/0
B       10.0.1.2/32 [200/2] via 2.2.2.2, 00:01:42
B       10.0.2.2/32 [200/2] via 2.2.2.2, 00:01:42
O       10.0.1.1/32 [110/2] via 10.255.0.18, 00:09:14, GigabitEthernet4/0
C       10.0.0.1/32 is directly connected, Loopback100
C       10.255.0.20/30 is directly connected, GigabitEthernet5/0
C       10.255.0.16/30 is directly connected, GigabitEthernet4/0
B       10.255.0.28/30 [200/0] via 2.2.2.2, 00:01:42
B       10.255.0.24/30 [200/0] via 2.2.2.2, 00:01:42
O       10.255.0.4/30 [110/4] via 10.255.0.2, 00:09:14, GigabitEthernet3/0
C       10.255.0.0/30 is directly connected, GigabitEthernet3/0
O       10.255.0.12/30 [110/3] via 10.255.0.2, 00:09:14, GigabitEthernet3/0
O       10.255.0.8/30 [110/2] via 10.255.0.2, 00:09:14, GigabitEthernet3/0
     192.168.0.0/32 is subnetted, 3 subnets
O       192.168.0.1 [110/2] via 10.255.0.2, 00:09:14, GigabitEthernet3/0
O       192.168.0.2 [110/4] via 10.255.0.2, 00:09:14, GigabitEthernet3/0
O       192.168.0.3 [110/3] via 10.255.0.2, 00:09:14, GigabitEthernet3/0
PEx#
```

Show ip vrf



```
Dynamips(6): PEx, Console port
PEx#sh ip vrf
  Name                             Default RD          Interfaces
  COMPANY                          1:1                 Lo100
                                                       Gi3/0
                                                       Gi4/0
                                                       Gi5/0
PEx#
```

Show mpls forwarding-table

```
Dynamips(6): PEx, Console port
PEx#sh mpls forwarding-table
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
16     Pop tag     3.3.3.3/32        0          Gi1/0      20.20.20.2
17     Pop tag     20.20.20.8/30     0          Gi1/0      20.20.20.2
18     Pop tag     20.20.20.16/30    0          Gi2/0      20.20.20.6
       Pop tag     20.20.20.16/30    0          Gi1/0      20.20.20.2
19     Pop tag     4.4.4.4/32        0          Gi2/0      20.20.20.6
20     Pop tag     20.20.20.12/30    0          Gi2/0      20.20.20.6
21     20          2.2.2.2/32        0          Gi1/0      20.20.20.2
22     Aggregate   10.0.0.1/32[V]    11058
23     Pop tag     10.0.1.1/32[V]    89089      Gi4/0      10.255.0.18
24     Pop tag     10.0.2.1/32[V]    66430      Gi5/0      10.255.0.22
25     Aggregate   10.255.0.0/30[V]  0
26     26          10.255.0.4/30[V]  0          Gi3/0      10.255.0.2
27     Pop tag     10.255.0.8/30[V]  0          Gi3/0      10.255.0.2
28     22          10.255.0.12/30[V] 0          Gi3/0      10.255.0.2
29     Aggregate   10.255.0.16/30[V] 0
30     Aggregate   10.255.0.20/30[V] 0
31     Pop tag     192.168.0.1/32[V] 113232     Gi3/0      10.255.0.2
32     27          192.168.0.2/32[V] 112207     Gi3/0      10.255.0.2
33     23          192.168.0.3/32[V] 610        Gi3/0      10.255.0.2
34     23          10.0.0.2/32[V]    0          Gi1/0      20.20.20.2
35     24          10.0.1.2/32[V]    109268     Gi1/0      20.20.20.2
36     25          10.0.2.2/32[V]    81848      Gi1/0      20.20.20.2
37     26          10.255.0.24/30[V] 0          Gi1/0      20.20.20.2
38     27          10.255.0.28/30[V] 0          Gi1/0      20.20.20.2
PEx#
```

EDGE1

Show interface description

```
Dynamips(8): EdgeRouter1, Console port
EdgeRouter1#sh int desc
Interface                      Status         Protocol Description
Fa0/0                          admin down     down
Gi1/0                          up             up       *** LINK to PEx (MPLS CsC ISP) ***
Gi2/0                          up             up       *** LINK to CORE Router COMPANY ***
Gi3/0                          admin down     down
Gi4/0                          admin down     down
Lo0                            up             up       *** MANAGEMENT PURPOSES ***
EdgeRouter1#
```

Show ip bgp summary

```
Dynamips(8): EdgeRouter1, Console port
EdgeRouter1#sh ip bgp summary
BGP router identifier 192.168.0.1, local AS number 100
BGP table version is 1, main routing table version 1

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
10.0.1.1        4   100    8175    4107        1    0    0 02:53:46        0
10.0.1.2        4   100    7274    3656        1    0    0 02:52:33        0
10.0.2.1        4   100    6205    3126        1    0    0 02:53:56        0
10.0.2.2        4   100    6168    3108        1    0    0 02:52:53        0
192.168.0.2     4   100     605     599        1    0    0 09:20:27        0
192.168.0.3     4   100    8122    4082        1    0    0 09:58:56        0
EdgeRouter1#
```

Show ip ospf 100 neigbor

Dynamips(8): EdgeRouter1, Console port

```
EdgeRouter1#sh ip ospf 100 neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
COREROUTER_Lo0    1   FULL/BDR        00:00:32    10.255.0.10     GigabitEthernet2/0
PEx               1   FULL/BDR        00:00:37    10.255.0.1      GigabitEthernet1/0
EdgeRouter1#
```

Show ip route

Dynamips(8): EdgeRouter1, Console port

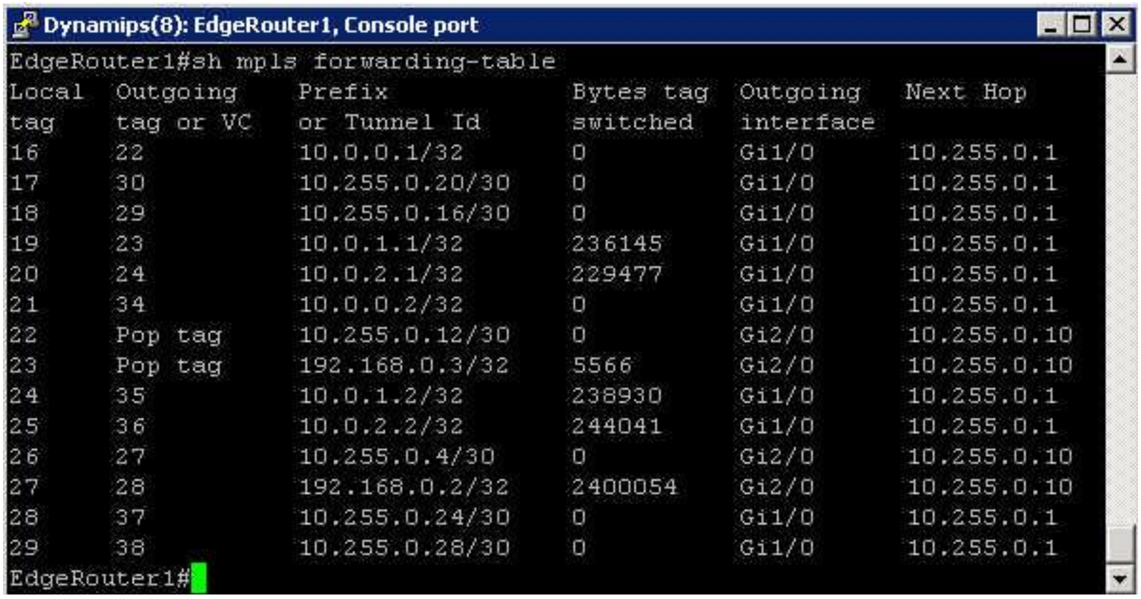
```
EdgeRouter1#sh ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 14 subnets, 2 masks
O IA    10.0.0.2/32 [110/2] via 10.255.0.1, 02:51:27, GigabitEthernet1/0
O       10.0.2.1/32 [110/3] via 10.255.0.1, 02:52:22, GigabitEthernet1/0
O IA    10.0.1.2/32 [110/3] via 10.255.0.1, 02:51:27, GigabitEthernet1/0
O IA    10.0.2.2/32 [110/3] via 10.255.0.1, 02:51:27, GigabitEthernet1/0
O       10.0.1.1/32 [110/3] via 10.255.0.1, 02:52:22, GigabitEthernet1/0
O       10.0.0.1/32 [110/2] via 10.255.0.1, 02:52:22, GigabitEthernet1/0
O       10.255.0.20/30 [110/2] via 10.255.0.1, 02:52:22, GigabitEthernet1/0
O       10.255.0.16/30 [110/2] via 10.255.0.1, 02:52:22, GigabitEthernet1/0
O IA    10.255.0.28/30 [110/2] via 10.255.0.1, 02:51:27, GigabitEthernet1/0
O IA    10.255.0.24/30 [110/2] via 10.255.0.1, 02:51:27, GigabitEthernet1/0
O       10.255.0.4/30 [110/3] via 10.255.0.10, 02:52:22, GigabitEthernet2/0
C       10.255.0.0/30 is directly connected, GigabitEthernet1/0
O       10.255.0.12/30 [110/2] via 10.255.0.10, 02:52:22, GigabitEthernet2/0
C       10.255.0.8/30 is directly connected, GigabitEthernet2/0
     192.168.0.0/32 is subnetted, 3 subnets
C       192.168.0.1 is directly connected, Loopback0
O       192.168.0.2 [110/3] via 10.255.0.10, 02:52:22, GigabitEthernet2/0
O       192.168.0.3 [110/2] via 10.255.0.10, 02:52:22, GigabitEthernet2/0
EdgeRouter1#
```

Show ip vrf

Dynamips(8): EdgeRouter1, Console port

```
EdgeRouter1#sh ip vrf
  Name                             Default RD          Interfaces
  CUSTOMERA                        100:1
  CUSTOMERB                        100:2
```

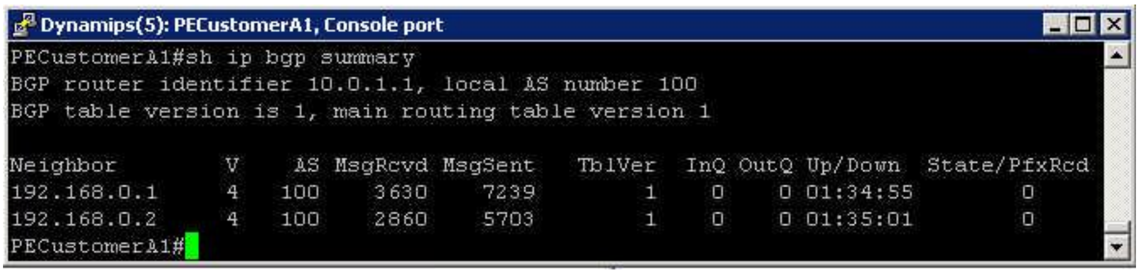
Show mpls forwarding-table


Dynamips(8): EdgeRouter1, Console port

```
EdgeRouter1#sh mpls forwarding-table
Local  Outgoing    Prefix            Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
16     22          10.0.0.1/32       0          Gi1/0       10.255.0.1
17     30          10.255.0.20/30    0          Gi1/0       10.255.0.1
18     29          10.255.0.16/30    0          Gi1/0       10.255.0.1
19     23          10.0.1.1/32       236145     Gi1/0       10.255.0.1
20     24          10.0.2.1/32       229477     Gi1/0       10.255.0.1
21     34          10.0.0.2/32       0          Gi1/0       10.255.0.1
22     Pop tag     10.255.0.12/30    0          Gi2/0       10.255.0.10
23     Pop tag     192.168.0.3/32    5566       Gi2/0       10.255.0.10
24     35          10.0.1.2/32       238930     Gi1/0       10.255.0.1
25     36          10.0.2.2/32       244041     Gi1/0       10.255.0.1
26     27          10.255.0.4/30     0          Gi2/0       10.255.0.10
27     28          192.168.0.2/32    2400054    Gi2/0       10.255.0.10
28     37          10.255.0.24/30    0          Gi1/0       10.255.0.1
29     38          10.255.0.28/30    0          Gi1/0       10.255.0.1
EdgeRouter1#
```

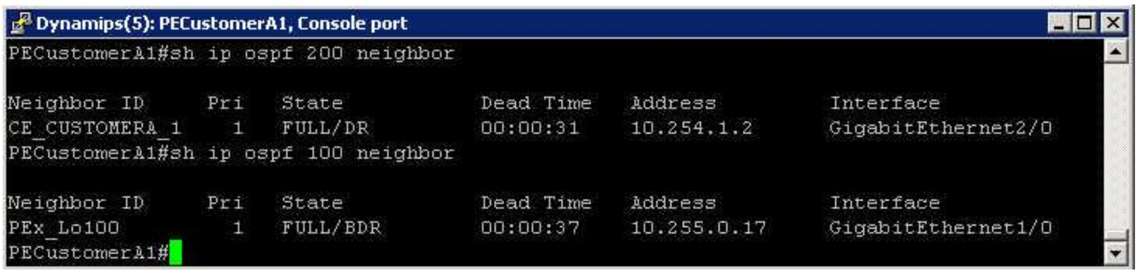
PE_CustomerA1

Show ip bgp summary


Dynamips(5): PECustomerA1, Console port

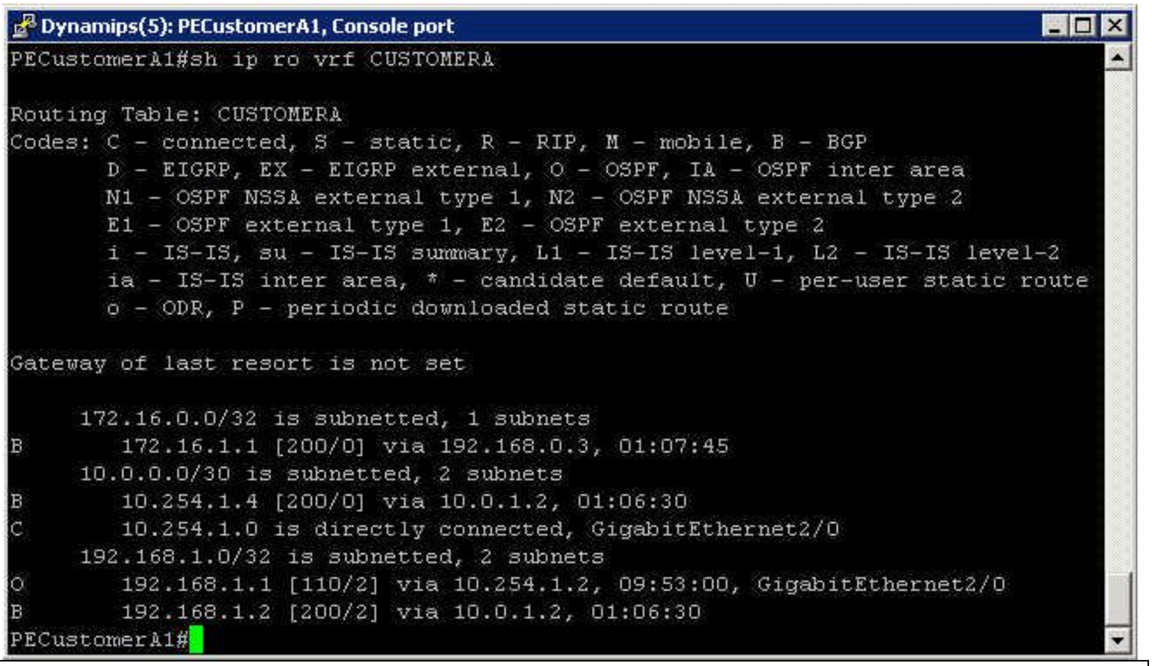
```
PECustomerA1#sh ip bgp summary
BGP router identifier 10.0.1.1, local AS number 100
BGP table version is 1, main routing table version 1

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
192.168.0.1     4   100    3630    7239        1    0    0 01:34:55        0
192.168.0.2     4   100    2860    5703        1    0    0 01:35:01        0
PECustomerA1#
```

Show ip ospf neigbor


Dynamips(5): PECustomerA1, Console port

```
PECustomerA1#sh ip ospf 200 neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
CE_CUSTOMERA_1    1   FULL/DR         00:00:31    10.254.1.2      GigabitEthernet2/0
PECustomerA1#sh ip ospf 100 neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
PEx_Lo100         1   FULL/BDR        00:00:37    10.255.0.17     GigabitEthernet1/0
PECustomerA1#
```

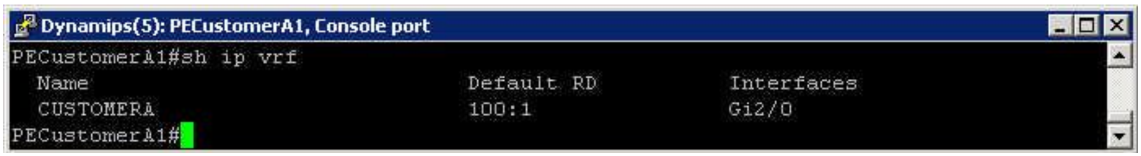
Show ip route vrf CUSTOMERA



Dynamips(5): PECustomerA1, Console port

```
PECustomerA1#sh ip ro vrf CUSTOMERA

Routing Table: CUSTOMERA
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/32 is subnetted, 1 subnets
B       172.16.1.1 [200/0] via 192.168.0.3, 01:07:45
     10.0.0.0/30 is subnetted, 2 subnets
B       10.254.1.4 [200/0] via 10.0.1.2, 01:06:30
C       10.254.1.0 is directly connected, GigabitEthernet2/0
     192.168.1.0/32 is subnetted, 2 subnets
O       192.168.1.1 [110/2] via 10.254.1.2, 09:53:00, GigabitEthernet2/0
B       192.168.1.2 [200/2] via 10.0.1.2, 01:06:30
PECustomerA1#
```

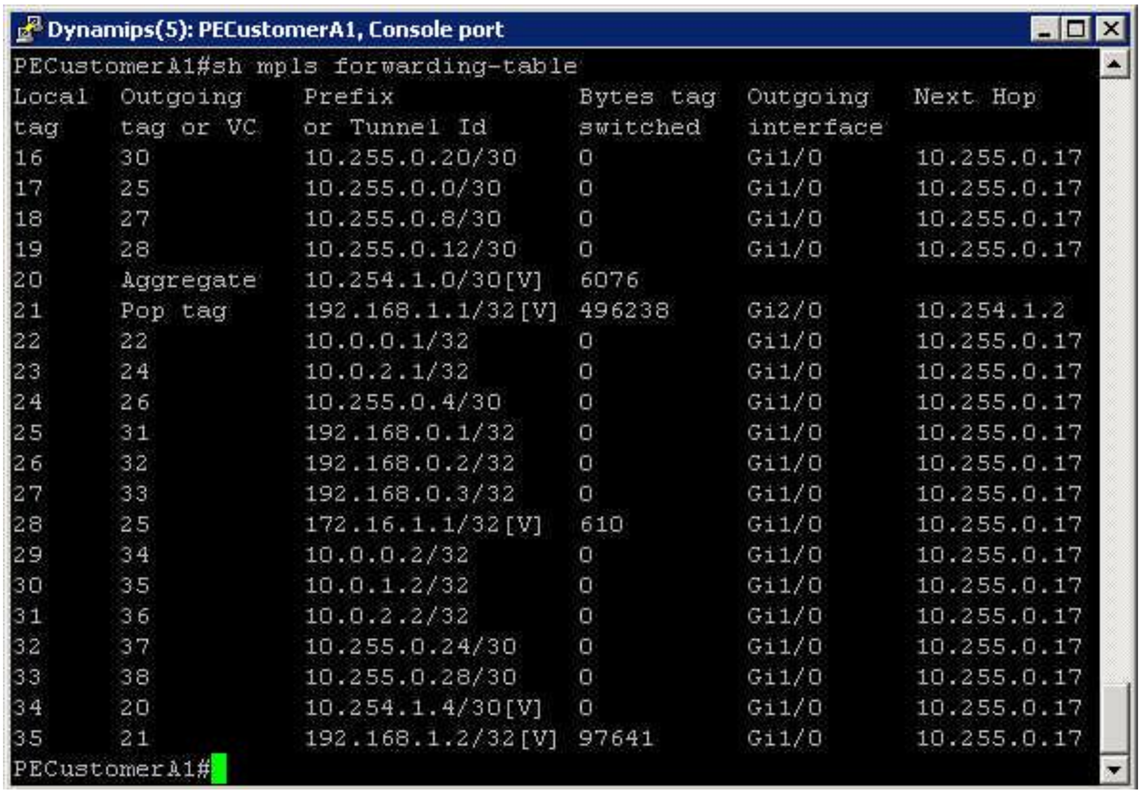
Show ip vrf



Dynamips(5): PECustomerA1, Console port

```
PECustomerA1#sh ip vrf
  Name                             Default RD          Interfaces
  CUSTOMERA                        100:1               Gi2/0
PECustomerA1#
```

Show mpls forwarding-table



Dynamips(5): PECustomerA1, Console port

```
PECustomerA1#sh mpls forwarding-table
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
16     30          10.255.0.20/30    0          Gi1/0      10.255.0.17
17     25          10.255.0.0/30     0          Gi1/0      10.255.0.17
18     27          10.255.0.8/30     0          Gi1/0      10.255.0.17
19     28          10.255.0.12/30    0          Gi1/0      10.255.0.17
20     Aggregate   10.254.1.0/30[V]  6076
21     Pop tag     192.168.1.1/32[V] 496238     Gi2/0      10.254.1.2
22     22          10.0.0.1/32       0          Gi1/0      10.255.0.17
23     24          10.0.2.1/32       0          Gi1/0      10.255.0.17
24     26          10.255.0.4/30     0          Gi1/0      10.255.0.17
25     31          192.168.0.1/32    0          Gi1/0      10.255.0.17
26     32          192.168.0.2/32    0          Gi1/0      10.255.0.17
27     33          192.168.0.3/32    0          Gi1/0      10.255.0.17
28     25          172.16.1.1/32[V]  610        Gi1/0      10.255.0.17
29     34          10.0.0.2/32       0          Gi1/0      10.255.0.17
30     35          10.0.1.2/32       0          Gi1/0      10.255.0.17
31     36          10.0.2.2/32       0          Gi1/0      10.255.0.17
32     37          10.255.0.24/30    0          Gi1/0      10.255.0.17
33     38          10.255.0.28/30    0          Gi1/0      10.255.0.17
34     20          10.254.1.4/30[V]  0          Gi1/0      10.255.0.17
35     21          192.168.1.2/32[V] 97641      Gi1/0      10.255.0.17
PECustomerA1#
```

B. Device Configurations

VRF Scenario Configurations

R1

```
Current configuration : 1374 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R1
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
!
ip cef
!
!
ip vrf Cliente1
 rd 192.168.1.1:100
 route-target export 192.168.1.255:100
 route-target import 192.168.1.255:100
!
ip vrf Cliente2
 rd 192.168.1.1:200
 route-target export 192.168.1.255:200
 route-target import 192.168.1.255:200
!
!
interface GigabitEthernet3/0.1
 encapsulation dot1Q 1 native
 ip vrf forwarding Cliente1
 ip address 192.168.1.10 255.255.255.0
!
interface GigabitEthernet3/0.2
 encapsulation dot1Q 2
 ip vrf forwarding Cliente2
 ip address 192.168.1.20 255.255.255.0
!
ip forward-protocol nd
!
no ip http server
!
!
control-plane
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
end
```

R2

```
Building configuration...

Current configuration : 1276 bytes
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R2
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
!
ip cef
!
!
ip vrf Cliente1
 rd 192.168.1.1:100
 route-target export 192.168.1.255:100
 route-target import 192.168.1.255:100
!
ip vrf Cliente2
 rd 192.168.1.1:200
 route-target export 192.168.1.255:200
 route-target import 192.168.1.255:200
!
!
interface GigabitEthernet3/0.1
 encapsulation dot1Q 1 native
 ip vrf forwarding Cliente1
 ip address 192.168.1.1 255.255.255.0
!
interface GigabitEthernet3/0.2
 encapsulation dot1Q 2
 ip vrf forwarding Cliente2
 ip address 192.168.1.2 255.255.255.0
!
ip forward-protocol nd
!
no ip http server
control-plane
!
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
!
!
end
```

VPN MPLS Configuration

Cliente1

```
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname Cliente1
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
!
ip cef
!
!
interface Loopback1
 ip address 101.101.101.101 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 ip address 10.2.0.2 255.255.255.0
 ip ospf network point-to-point
 negotiation auto
!
router ospf 2
 router-id 101.101.101.101
 log-adjacency-changes
 passive-interface default
 no passive-interface GigabitEthernet1/0
 network 10.2.0.0 0.0.0.255 area 0
 network 101.101.101.101 0.0.0.0 area 0
!
ip default-gateway 201.201.201.201
ip forward-protocol nd
!
no ip http server
!
!
control-plane
!
!
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
!
!
end
```

PE_Cliente1

```
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname PE_Cliente1
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
!
ip cef
!
!
ip vrf Cliente1
 rd 65000:43
 route-target export 65000:43
 route-target import 65000:43
!
mpls label protocol ldp
!
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Loopback1
 ip vrf forwarding Cliente1
 ip address 201.201.201.201 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 mtu 4470
 ip address 10.10.10.5 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 ip vrf forwarding Cliente1
 ip address 10.2.0.1 255.255.255.0
 ip ospf network point-to-point
 negotiation auto
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 2 vrf Cliente1
 router-id 201.201.201.201
 log-adjacency-changes
 redistribute bgp 65000 metric-type 1 subnets
 passive-interface default
 no passive-interface GigabitEthernet2/0
```

```
 network 10.2.0.0 0.0.0.255 area 0
 network 201.201.201.201 0.0.0.0 area 0
!
router ospf 1
 router-id 3.3.3.3
 log-adjacency-changes
 network 3.3.3.3 0.0.0.0 area 0
 network 10.10.10.5 0.0.0.0 area 0
!
router bgp 65000
 no synchronization
 bgp router-id 3.3.3.3
 bgp log-neighbor-changes
 neighbor 1.1.1.1 remote-as 65000
 neighbor 1.1.1.1 update-source Loopback0
 no auto-summary
 !
 address-family vpnv4
  neighbor 1.1.1.1 activate
  neighbor 1.1.1.1 send-community both
 exit-address-family
 !
 address-family ipv4 vrf Cliente1
  redistribute connected
  redistribute ospf 2 vrf Cliente1
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
alias exec shc sh ip ro vrf Cliente1
!
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
!
!
end
```

Cliente2

```
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname Cliente2
!
boot-start-marker
```

```
boot-end-marker
!
!
no aaa new-model
!
!
ip cef
!
!
interface Loopback0
 ip address 50.50.50.51 255.255.255.255
!
!
interface GigabitEthernet1/0
 ip address 10.3.0.2 255.255.255.252
 ip ospf network point-to-point
 negotiation auto
!
!
 router ospf 3
 router-id 50.50.50.51
 log-adjacency-changes
 passive-interface default
 no passive-interface GigabitEthernet1/0
 network 10.3.0.0 0.0.0.255 area 0
 network 50.50.50.51 0.0.0.0 area 0
!
ip forward-protocol nd
!
no ip http server
!
control-plane
!
!
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
!
!
end
```

PE_Cliente2

```
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname PE_Cliente2
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
!
ip cef
!
!
ip vrf Cliente2
 rd 50:50
```

```
 route-target export 50:50
 route-target import 50:50
!
mpls label protocol ldp
!
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Loopback1
 ip vrf forwarding Cliente2
 ip address 50.50.50.50 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 mtu 4470
 ip address 10.10.10.9 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 ip vrf forwarding Cliente2
 ip address 10.3.0.1 255.255.255.252
 ip ospf network point-to-point
 negotiation auto
!
router ospf 3 vrf Cliente2
 router-id 50.50.50.50
 log-adjacency-changes
 redistribute bgp 65000 metric-type 1 subnets
 passive-interface default
 no passive-interface GigabitEthernet2/0
 network 10.3.0.0 0.0.0.255 area 0
 network 50.50.50.50 0.0.0.0 area 0
!
router ospf 1
 router-id 4.4.4.4
 log-adjacency-changes
 network 4.4.4.4 0.0.0.0 area 0
 network 10.10.10.9 0.0.0.0 area 0
!
router bgp 65000
 no synchronization
 bgp router-id 4.4.4.4
 bgp log-neighbor-changes
 neighbor 1.1.1.1 remote-as 65000
 neighbor 1.1.1.1 update-source Loopback0
 no auto-summary
 !
 address-family vpnv4
  neighbor 1.1.1.1 activate
  neighbor 1.1.1.1 send-community both
 exit-address-family
 !
 address-family ipv4 vrf Cliente2
  redistribute connected
  redistribute ospf 3 vrf Cliente2
  no synchronization
 exit-address-family
!
ip forward-protocol nd
```

```
!
no ip http server
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
alias exec shof sh run | b router
alias exec shc2 sh ip ro vrf Cliente2
alias exec shc sh ip ro vrf Cliente2
!
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
!
!
end
```

Provider Company

```
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname Provider_Company
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
!
ip cef
!
!
ip vrf Cliente1
 rd 65000:43
 route-target export 65000:43
 route-target import 65000:43
!
ip vrf Cliente2
 rd 50:50
 route-target export 50:50
 route-target import 50:50
!
mpls label protocol ldp
!
!
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface Loopback1
 ip vrf forwarding Cliente1
 ip address 100.100.100.100 255.255.255.255
```

```
!
interface Loopback2
 ip vrf forwarding Cliente2
 ip address 120.100.100.100 255.255.255.255
!
!
interface GigabitEthernet1/0
 mtu 4470
 ip address 10.10.10.1 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 no ip address
 ip ospf network point-to-point
 negotiation auto
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 1
 router-id 1.1.1.1
 log-adjacency-changes
 network 1.1.1.1 0.0.0.0 area 0
 network 10.10.10.1 0.0.0.0 area 0
!
router bgp 65000
 no synchronization
 bgp router-id 1.1.1.1
 bgp log-neighbor-changes
 neighbor 3.3.3.3 remote-as 65000
 neighbor 3.3.3.3 update-source Loopback0
 neighbor 4.4.4.4 remote-as 65000
 neighbor 4.4.4.4 update-source Loopback0
 no auto-summary
 !
 address-family vpnv4
  neighbor 3.3.3.3 activate
  neighbor 3.3.3.3 send-community both
  neighbor 4.4.4.4 activate
  neighbor 4.4.4.4 send-community both
 exit-address-family
 !
 address-family ipv4 vrf Cliente2
  redistribute connected
  no synchronization
 exit-address-family
 !
 address-family ipv4 vrf Cliente1
  redistribute connected
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
```

```
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec shc2 sh ip ro vrf Cliente2
alias exec shc1 sh ip ro vrf Cliente1
!
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
!
!
end
```

P

```
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname P
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
!
ip cef
!
!
mpls label protocol ldp
!
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 mtu 4470
 ip address 10.10.10.2 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 mtu 4470
 ip address 10.10.10.6 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 mtu 4470
 ip address 10.10.10.10 255.255.255.252
 negotiation auto
 mpls label protocol ldp
```

```
 mpls ip
!
router ospf 1
 router-id 2.2.2.2
 log-adjacency-changes
 network 2.2.2.2 0.0.0.0 area 0
 network 10.10.10.2 0.0.0.0 area 0
 network 10.10.10.6 0.0.0.0 area 0
 network 10.10.10.10 0.0.0.0 area 0
!
ip forward-protocol nd
!
no ip http server
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
!
line con 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
!
!
end
```

VPN MPLS CsC

CECustomerA1

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname CECustomerA1
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$Z4JA$aUi6p4TD8FGvL9OuHHA3i/
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host CE_CUSTOMERA_1 192.168.1.1
ip host CE_CUSTOMERA_2 192.168.1.2
ip host CE_CUSTOMERA_DATACENTER 172.16.1.1
ip host CE_CUSTOMERB_1 192.168.2.1
ip host CE_CUSTOMERB_2 192.168.2.2
ip host CE_CUSTOMERB_DATACENTER 172.16.2.1
ip host CECUSTOMERA1_Gi2-0 10.254.1.1
!
!
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
!
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 192.168.1.1 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PE CUSTOMER A1 ***
 mtu 4470
 ip address 10.254.1.2 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 no ip address
 shutdown
```

```
 negotiation auto
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 65535
 router-id 192.168.1.1
 log-adjacency-changes
 redistribute bgp 65535
 network 10.254.1.2 0.0.0.0 area 65535
 network 192.168.1.1 0.0.0.0 area 65535
!
router bgp 65535
 bgp router-id 192.168.1.1
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 192.168.1.2 remote-as 65535
 neighbor 192.168.1.2 update-source Loopback0
 !
 address-family ipv4
  redistribute connected
  redistribute ospf 65535 match internal
  neighbor 192.168.1.2 activate
  neighbor 192.168.1.2 send-community both
  no auto-summary
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
ip ospf name-lookup
!
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
!
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

CECustomerA2

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname CECustomerA2
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$JewI$E5At4qtX5u3IANVWzSrhD0
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host CE_CUSTOMERA_1 192.168.1.1
ip host CE_CUSTOMERA_2 192.168.1.2
ip host CE_CUSTOMERA_DATACENTER 172.16.1.1
ip host CE_CUSTOMERB_1 192.168.2.1
ip host CE_CUSTOMERB_2 192.168.2.2
ip host CE_CUSTOMERB_DATACENTER 172.16.2.1
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
!
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 192.168.1.2 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PE CUSTOMER A2 ***
 mtu 4470
 ip address 10.254.1.6 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet3/0
```

```
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 65535
 router-id 192.168.1.2
 log-adjacency-changes
 redistribute bgp 65535
 network 10.254.1.6 0.0.0.0 area 65535
 network 192.168.1.2 0.0.0.0 area 65535
!
router bgp 65535
 bgp router-id 192.168.1.2
 bgp log-neighbor-changes
 neighbor 192.168.1.1 remote-as 65535
 neighbor 192.168.1.1 update-source Loopback0
 !
 address-family ipv4
  redistribute connected
  redistribute ospf 65535 match internal
  neighbor 192.168.1.1 activate
  neighbor 192.168.1.1 send-community both
  no auto-summary
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

CECustomerB1

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname CECustomerB1
!
```

```
boot-start-marker
boot-end-marker
!
enable secret 5 $1$C/57$TwAjqmQlPkwHFKgeyh.VX1
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host CE_CUSTOMERA_1 192.168.1.1
ip host CE_CUSTOMERA_2 192.168.1.2
ip host CE_CUSTOMERA_DATACENTER 172.16.1.1
ip host CE_CUSTOMERB_1 192.168.2.1
ip host CE_CUSTOMERB_2 192.168.2.2
ip host CE_CUSTOMERB_DATACENTER 172.16.2.1
!
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
!
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 192.168.2.1 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PE CUSTOMER B1 ***
 mtu 4470
 ip address 10.254.2.2 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 65535
 router-id 192.168.2.1
 log-adjacency-changes
 redistribute bgp 65535
 network 10.254.2.2 0.0.0.0 area 65535
 network 192.168.2.1 0.0.0.0 area 65535
!
```

```
router bgp 65535
 bgp router-id 192.168.2.1
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 192.168.2.2 remote-as 100
 neighbor 192.168.2.2 update-source Loopback0
 !
 address-family ipv4
  redistribute connected
  redistribute ospf 65535 match internal
  neighbor 192.168.2.2 activate
  neighbor 192.168.2.2 send-community both
  no auto-summary
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
!
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

CECustomerB2

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname CECustomerB2
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$tfc1$hbr.GNmLyKHDCMBKA1lP8.
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
```

```
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host CE_CUSTOMERA_1 192.168.1.1
ip host CE_CUSTOMERA_2 192.168.1.2
ip host CE_CUSTOMERA_DATACENTER 172.16.1.1
ip host CE_CUSTOMERB_1 192.168.2.1
ip host CE_CUSTOMERB_2 192.168.2.2
ip host CE_CUSTOMERB_DATACENTER 172.16.2.1
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 192.168.2.2 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PE CUSTOMER B2 ***
 mtu 4470
 ip address 10.254.2.6 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 65535
 router-id 192.168.2.2
 log-adjacency-changes
 redistribute bgp 65535
 network 10.254.2.6 0.0.0.0 area 65535
 network 192.168.2.2 0.0.0.0 area 65535
!
router bgp 65535
 bgp router-id 192.168.2.2
 bgp log-neighbor-changes
 neighbor 192.168.2.1 remote-as 65535
 neighbor 192.168.2.1 update-source Loopback0
 !
 address-family ipv4
  redistribute connected
  redistribute ospf 65535 match internal
```

```
  neighbor 192.168.2.1 activate
  neighbor 192.168.2.1 send-community both
  no auto-summary
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

CORERouter

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname CORERouter
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$GsQO$U19CKozVUAfAiBSwEtlRH1
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host CE_CUSTOMERA_1 192.168.1.1
ip host CE_CUSTOMERA_2 192.168.1.2
ip host CE_CUSTOMERA_DATACENTER 172.16.1.1
ip host CE_CUSTOMERB_1 192.168.2.1
ip host CE_CUSTOMERB_2 192.168.2.2
ip host CE_CUSTOMERB_DATACENTER 172.16.2.1
ip host EDGE_1 192.168.0.1
ip host EDGE_2 192.168.0.2
!
```

```
!
ip vrf CUSTOMERA
 rd 100:1
 route-target export 100:1
 route-target import 100:1
!
ip vrf CUSTOMERB
 rd 100:2
 route-target export 100:2
 route-target import 100:2
!
mpls label protocol ldp
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 192.168.0.3 255.255.255.255
!
interface Loopback2000
 description *** CUSTOMER A NETWORK ***
 ip vrf forwarding CUSTOMERA
 ip address 172.16.1.1 255.255.255.255
!
interface Loopback2001
 description *** CUSTOMER B NETWORK ***
 ip vrf forwarding CUSTOMERB
 ip address 172.16.2.1 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to Edge Router 1 COMPANY ***
 mtu 4470
 ip address 10.255.0.10 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to Edge Router 2 COMPANY ***
 mtu 4470
 ip address 10.255.0.14 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 100
 router-id 192.168.0.3
 log-adjacency-changes
```

```
 network 10.255.0.10 0.0.0.0 area 100
 network 10.255.0.14 0.0.0.0 area 100
 network 192.168.0.3 0.0.0.0 area 100
!
router bgp 100
 bgp router-id 192.168.0.3
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 192.168.0.1 remote-as 100
 neighbor 192.168.0.1 update-source Loopback0
 neighbor 192.168.0.2 remote-as 100
 neighbor 192.168.0.2 update-source Loopback0
 !
 address-family ipv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.1 send-community both
  neighbor 192.168.0.2 activate
  neighbor 192.168.0.2 send-community both
  no auto-summary
  no synchronization
 exit-address-family
 !
 address-family vpnv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.1 send-community both
  neighbor 192.168.0.2 activate
  neighbor 192.168.0.2 send-community both
  bgp scan-time 15
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERB
  redistribute connected
  no synchronization
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERA
  redistribute connected
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
ip ospf name-lookup
!
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
```

```
!
end
```

EdgeRouter1

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname EdgeRouter1
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$qViJ$YLBLwb0CWKcX4RUl8SqI2.
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host CE_CUSTOMERA_DATACENTER 172.16.1.1
ip host PEx 10.0.0.1
ip host COREROUTER_Lo0 192.168.0.3
!
!
ip vrf CUSTOMERA
 rd 100:1
 route-target export 100:1
 route-target import 100:1
!
ip vrf CUSTOMERB
 rd 100:2
 route-target export 100:2
 route-target import 100:2
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 192.168.0.1 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PEx (MPLS CsC ISP) ***
 mtu 4470
 ip address 10.255.0.2 255.255.255.252
 negotiation auto
 mpls label protocol ldp
```

```
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to CORE Router COMPANY ***
 mtu 4470
 ip address 10.255.0.9 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 100
 router-id 192.168.0.1
 log-adjacency-changes
 network 10.255.0.2 0.0.0.0 area 100
 network 10.255.0.9 0.0.0.0 area 100
 network 192.168.0.1 0.0.0.0 area 100
!
router bgp 100
 bgp router-id 192.168.0.1
 no bgp default ipv4-unicast
 bgp cluster-id 1
 bgp log-neighbor-changes
 neighbor 10.0.1.1 remote-as 100
 neighbor 10.0.1.1 update-source Loopback0
 neighbor 10.0.1.2 remote-as 100
 neighbor 10.0.1.2 update-source Loopback0
 neighbor 10.0.2.1 remote-as 100
 neighbor 10.0.2.1 update-source Loopback0
 neighbor 10.0.2.2 remote-as 100
 neighbor 10.0.2.2 update-source Loopback0
 neighbor 192.168.0.2 remote-as 100
 neighbor 192.168.0.2 update-source Loopback0
 neighbor 192.168.0.3 remote-as 100
 neighbor 192.168.0.3 update-source Loopback0
 !
 address-family ipv4
  neighbor 10.0.1.1 activate
  neighbor 10.0.1.1 send-community both
  neighbor 10.0.1.1 route-reflector-client
  neighbor 10.0.1.2 activate
  neighbor 10.0.1.2 send-community both
  neighbor 10.0.1.2 route-reflector-client
  neighbor 10.0.2.1 activate
  neighbor 10.0.2.1 send-community both
  neighbor 10.0.2.1 route-reflector-client
  neighbor 10.0.2.2 activate
  neighbor 10.0.2.2 send-community both
  neighbor 10.0.2.2 route-reflector-client
  neighbor 192.168.0.2 activate
  neighbor 192.168.0.2 send-community both
  neighbor 192.168.0.3 activate
  neighbor 192.168.0.3 send-community both
  neighbor 192.168.0.3 route-reflector-client
  no auto-summary
  no synchronization
 exit-address-family
```

```
 !
 address-family vpnv4
  neighbor 10.0.1.1 activate
  neighbor 10.0.1.1 send-community both
  neighbor 10.0.1.1 route-reflector-client
  neighbor 10.0.1.2 activate
  neighbor 10.0.1.2 send-community both
  neighbor 10.0.1.2 route-reflector-client
  neighbor 10.0.2.1 activate
  neighbor 10.0.2.1 send-community both
  neighbor 10.0.2.1 route-reflector-client
  neighbor 10.0.2.2 activate
  neighbor 10.0.2.2 send-community both
  neighbor 10.0.2.2 route-reflector-client
  neighbor 192.168.0.2 activate
  neighbor 192.168.0.2 send-community both
  neighbor 192.168.0.3 activate
  neighbor 192.168.0.3 send-community both
  neighbor 192.168.0.3 route-reflector-client
  bgp scan-time 15
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERB
  no synchronization
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERA
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
ip ospf name-lookup
!
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

EdgeRouter2

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
```

```
!
hostname EdgeRouter2
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$HZn4$QMrv8U07iBTWx4edG1AS.0
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host COREROUTER_Lo0 192.168.0.3
ip host PEy_Lo100 10.0.0.2
!
!
ip vrf CUSTOMERA
 rd 100:1
 route-target export 100:1
 route-target import 100:1
!
ip vrf CUSTOMERB
 rd 100:2
 route-target export 100:2
 route-target import 100:2
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 192.168.0.2 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PEy (MPLS CsC ISP) ***
 mtu 4470
 ip address 10.255.0.6 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to CORE Router COMPANY ***
 mtu 4470
 ip address 10.255.0.13 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
```

```
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 100
 router-id 192.168.0.2
 log-adjacency-changes
 network 10.255.0.6 0.0.0.0 area 100
 network 10.255.0.13 0.0.0.0 area 100
 network 192.168.0.2 0.0.0.0 area 100
!
router bgp 100
 bgp router-id 192.168.0.2
 no bgp default ipv4-unicast
 bgp cluster-id 1
 bgp log-neighbor-changes
 neighbor 10.0.1.1 remote-as 100
 neighbor 10.0.1.1 update-source Loopback0
 neighbor 10.0.1.2 remote-as 100
 neighbor 10.0.1.2 update-source Loopback0
 neighbor 10.0.2.1 remote-as 100
 neighbor 10.0.2.1 update-source Loopback0
 neighbor 10.0.2.2 remote-as 100
 neighbor 10.0.2.2 update-source Loopback0
 neighbor 192.168.0.1 remote-as 100
 neighbor 192.168.0.1 update-source Loopback0
 neighbor 192.168.0.3 remote-as 100
 neighbor 192.168.0.3 update-source Loopback0
 !
 address-family ipv4
  neighbor 10.0.1.1 activate
  neighbor 10.0.1.1 send-community both
  neighbor 10.0.1.1 route-reflector-client
  neighbor 10.0.1.2 activate
  neighbor 10.0.1.2 send-community both
  neighbor 10.0.1.2 route-reflector-client
  neighbor 10.0.2.1 activate
  neighbor 10.0.2.1 send-community both
  neighbor 10.0.2.1 route-reflector-client
  neighbor 10.0.2.2 activate
  neighbor 10.0.2.2 send-community both
  neighbor 10.0.2.2 route-reflector-client
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.1 send-community both
  neighbor 192.168.0.3 activate
  neighbor 192.168.0.3 send-community both
  neighbor 192.168.0.3 route-reflector-client
  no auto-summary
  no synchronization
 exit-address-family
 !
 address-family vpnv4
  neighbor 10.0.1.1 activate
  neighbor 10.0.1.1 send-community both
  neighbor 10.0.1.1 route-reflector-client
  neighbor 10.0.1.2 activate
  neighbor 10.0.1.2 send-community both
  neighbor 10.0.1.2 route-reflector-client
  neighbor 10.0.2.1 activate
  neighbor 10.0.2.1 send-community both
  neighbor 10.0.2.1 route-reflector-client
```

```
 neighbor 10.0.2.2 activate
 neighbor 10.0.2.2 send-community both
 neighbor 10.0.2.2 route-reflector-client
 neighbor 192.168.0.1 activate
 neighbor 192.168.0.1 send-community both
 neighbor 192.168.0.3 activate
 neighbor 192.168.0.3 send-community both
 neighbor 192.168.0.3 route-reflector-client
 bgp scan-time 15
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERB
  no synchronization
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERA
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
ip ospf name-lookup
!
mpls ldp router-id Loopback0 force
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

P

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname P
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
!
!
ip cef
ip host PEx 1.1.1.1
ip host PEy 2.2.2.2
ip host PEz 4.4.4.4
```

```
!
!
mpls label protocol ldp
!
!
interface Loopback0
 description *** MANAGEMENT ***
 ip address 3.3.3.3 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PEx (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.2 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to PEy (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.10 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 description *** LINK to PEz (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.18 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet4/0
 no ip address
 negotiation auto
!
router ospf 1
 router-id 3.3.3.3
 log-adjacency-changes
 network 3.3.3.3 0.0.0.0 area 1
 network 20.20.20.2 0.0.0.0 area 1
 network 20.20.20.10 0.0.0.0 area 1
 network 20.20.20.18 0.0.0.0 area 1
!
ip forward-protocol nd
!
no ip http server
!
ip ospf name-lookup
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
alias exec c config t
alias exec srb sh run | b router bgp
!
line con 0
 exec-timeout 0 0
```

```
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
 login
!
!
end
```

PECustomerA1

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname PECustomerA1
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$Rv21$ZuS.hcu5DJCIYEFY/gHh11
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host CE_CUSTOMERA_1 192.168.1.1
ip host CE_CUSTOMERA_2 192.168.1.2
ip host CE_CUSTOMERA_DATACENTER 172.16.1.1
ip host CE_CUSTOMERB_1 192.168.2.1
ip host CE_CUSTOMERB_2 192.168.2.2
ip host CE_CUSTOMERB_DATACENTER 172.16.2.1
ip host PEx_Lo100 10.0.0.1
!
!
ip vrf CUSTOMERA
 rd 100:1
 route-target export 100:1
 route-target import 100:1
!
username cisco password 0 cisco
!
ip telnet source-interface Loopback0
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 10.0.1.1 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
```

```
!
interface GigabitEthernet1/0
 description *** LINK to PEx (MPLS CsC ISP) ***
 mtu 4470
 ip address 10.255.0.18 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to CE CUSTOMER A1 ***
 mtu 4470
 ip vrf forwarding CUSTOMERA
 ip address 10.254.1.1 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 200 vrf CUSTOMERA
 router-id 10.254.1.1
 log-adjacency-changes
 redistribute bgp 100 metric-type 1 subnets
 network 10.254.1.1 0.0.0.0 area 65535
!
router ospf 100
 router-id 10.0.1.1
 log-adjacency-changes
 network 10.0.1.1 0.0.0.0 area 100
 network 10.255.0.18 0.0.0.0 area 100
!
router bgp 100
 bgp router-id 10.0.1.1
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 192.168.0.1 remote-as 100
 neighbor 192.168.0.1 update-source Loopback0
 neighbor 192.168.0.2 remote-as 100
 neighbor 192.168.0.2 update-source Loopback0
 !
 address-family ipv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.2 activate
  no auto-summary
  no synchronization
 exit-address-family
 !
 address-family vpnv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.1 send-community both
  neighbor 192.168.0.2 activate
  neighbor 192.168.0.2 send-community both
  bgp scan-time 15
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERA
  redistribute ospf 200 vrf CUSTOMERA match internal external 1 external 2
  no synchronization
 exit-address-family
!
ip forward-protocol nd
```

```
!
no ip http server
!
ip ospf name-lookup
!
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

PECustomerA2

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname PECustomerA2
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$f2Dl$252pfjylqbboDpwp5bJds1
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
!
!
ip vrf CUSTOMERA
 rd 100:1
 route-target export 100:1
 route-target import 100:1
!
!
username cisco password 0 cisco
!
!
```

```
ip telnet source-interface Loopback0
!
!interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 10.0.1.2 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PEy (MPLS CsC ISP) ***
 mtu 4470
 ip address 10.255.0.26 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to CE CUSTOMER A2 ***
 mtu 4470
 ip vrf forwarding CUSTOMERA
 ip address 10.254.1.5 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 200 vrf CUSTOMERA
 router-id 10.254.1.5
 log-adjacency-changes
 redistribute bgp 100 metric-type 1 subnets
 network 10.254.1.5 0.0.0.0 area 65535
!
router ospf 100
 router-id 10.0.1.2
 log-adjacency-changes
 network 10.0.1.2 0.0.0.0 area 100
 network 10.255.0.26 0.0.0.0 area 100
!
router bgp 100
 bgp router-id 10.0.1.2
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 192.168.0.1 remote-as 100
 neighbor 192.168.0.1 update-source Loopback0
 neighbor 192.168.0.2 remote-as 100
 neighbor 192.168.0.2 update-source Loopback0
 !
 address-family ipv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.2 activate
  no auto-summary
  no synchronization
 exit-address-family
```

```
 !
 address-family vpnv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.1 send-community both
  neighbor 192.168.0.2 activate
  neighbor 192.168.0.2 send-community both
  bgp scan-time 15
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERA
  redistribute ospf 200 vrf CUSTOMERA match internal external 1 external 2
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

PECustomerB1

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname PECustomerB1
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$2CrS$/VCgGETuPT6oNJGXPSbs30
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
```

```
!
!
ip vrf CUSTOMERB
 rd 100:2
 route-target export 100:2
 route-target import 100:2
!
username cisco password 0 cisco
ip telnet source-interface Loopback0
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 10.0.2.1 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PEx (MPLS CsC ISP) ***
 mtu 4470
 ip address 10.255.0.22 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to CE CUSTOMER B1 ***
 mtu 4470
 ip vrf forwarding CUSTOMERB
 ip address 10.254.2.1 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 200 vrf CUSTOMERB
 router-id 10.254.2.1
 log-adjacency-changes
 redistribute bgp 100 metric-type 1 subnets
 network 10.254.2.1 0.0.0.0 area 65535
!
router ospf 100
 router-id 10.0.2.1
 log-adjacency-changes
 network 10.0.2.1 0.0.0.0 area 100
 network 10.255.0.22 0.0.0.0 area 100
!
router bgp 100
 bgp router-id 10.0.2.1
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 192.168.0.1 remote-as 100
 neighbor 192.168.0.1 update-source Loopback0
 neighbor 192.168.0.2 remote-as 100
 neighbor 192.168.0.2 update-source Loopback0
```

```
!
 address-family ipv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.2 activate
  no auto-summary
  no synchronization
 exit-address-family
 !
 address-family vpnv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.1 send-community both
  neighbor 192.168.0.2 activate
  neighbor 192.168.0.2 send-community both
  bgp scan-time 15
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERB
  redistribute ospf 200 vrf CUSTOMERB match internal external 1 external 2
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

PECustomerB2

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname PECustomerB2
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$De47$kGTlJqBxkAH0Dg.2ud9qi/
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
```

```
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
!
!
ip vrf CUSTOMERB
 rd 100:2
 route-target export 100:2
 route-target import 100:2
!
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
!
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 10.0.2.2 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PEy (MPLS CsC ISP) ***
 mtu 4470
 ip address 10.255.0.30 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to CE CUSTOMER B2 ***
 mtu 4470
 ip vrf forwarding CUSTOMERB
 ip address 10.254.2.5 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
router ospf 200 vrf CUSTOMERB
 router-id 10.254.2.5
 log-adjacency-changes
 redistribute bgp 100 metric-type 1 subnets
 network 10.254.2.5 0.0.0.0 area 65535
!
router ospf 100
 router-id 10.0.2.2
```

```
 log-adjacency-changes
 network 10.0.2.2 0.0.0.0 area 100
 network 10.255.0.30 0.0.0.0 area 100
!
router bgp 100
 bgp router-id 10.0.2.2
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 192.168.0.1 remote-as 100
 neighbor 192.168.0.1 update-source Loopback0
 neighbor 192.168.0.2 remote-as 100
 neighbor 192.168.0.2 update-source Loopback0
 !
 address-family ipv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.2 activate
  no auto-summary
  no synchronization
 exit-address-family
 !
 address-family vpnv4
  neighbor 192.168.0.1 activate
  neighbor 192.168.0.1 send-community both
  neighbor 192.168.0.2 activate
  neighbor 192.168.0.2 send-community both
  bgp scan-time 15
 exit-address-family
 !
 address-family ipv4 vrf CUSTOMERB
  redistribute ospf 200 vrf CUSTOMERB match internal external 1 external 2
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

PEx

```
!
version 12.4
service timestamps debug datetime msec
```

```
service timestamps log datetime msec
no service password-encryption
!
hostname PEx
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$ikbc$zdHTPnc825wotmPOaVYEH/
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host P 3.3.3.3
ip host Edge1 192.168.0.1
ip host PECUSTOMERA1_Lo0 10.0.1.1
ip host PECUSTOMERB1_Lo0 10.0.2.1
ip host CE_CUSTOMERA_1 192.168.1.1
ip host CE_CUSTOMERA_2 192.168.1.2
ip host CE_CUSTOMERA_DATACENTER 172.16.1.1
ip host CE_CUSTOMERB_1 192.168.2.1
ip host CE_CUSTOMERB_2 192.168.2.2
ip host CE_CUSTOMERB_DATACENTER 172.16.2.1
ip host PEz 4.4.4.4
!
!
ip vrf COMPANY
 rd 1:1
 route-target export 1:1
 route-target import 1:1
!
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
!
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 1.1.1.1 255.255.255.255
!
interface Loopback100
 description *** IGP VRF COMPANY ***
 ip vrf forwarding COMPANY
 ip address 10.0.0.1 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to P (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.1 255.255.255.252
```

```
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to PEz (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.5 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 description *** LINK to Edge Router 1 COMPANY ***
 mtu 4470
 ip vrf forwarding COMPANY
 ip address 10.255.0.1 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet4/0
 description *** LINK to PE CUSTOMER A1 ***
 mtu 4470
 ip vrf forwarding COMPANY
 ip address 10.255.0.17 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet5/0
 description *** LINK to PE CUSTOMER B1 ***
 mtu 4470
 ip vrf forwarding COMPANY
 ip address 10.255.0.21 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
router ospf 100 vrf COMPANY
 router-id 10.0.0.1
 log-adjacency-changes
 redistribute bgp 1 metric-type 1 subnets
 network 10.0.0.1 0.0.0.0 area 100
 network 10.255.0.1 0.0.0.0 area 100
 network 10.255.0.17 0.0.0.0 area 100
 network 10.255.0.21 0.0.0.0 area 100
!
router ospf 1
 router-id 1.1.1.1
 log-adjacency-changes
 network 1.1.1.1 0.0.0.0 area 1
 network 20.20.20.1 0.0.0.0 area 1
 network 20.20.20.5 0.0.0.0 area 1
!
router bgp 1
 bgp router-id 1.1.1.1
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 2.2.2.2 remote-as 1
 neighbor 2.2.2.2 update-source Loopback0
 neighbor 4.4.4.4 remote-as 1
 neighbor 4.4.4.4 update-source Loopback0
 !
 address-family ipv4
```

```
  neighbor 2.2.2.2 activate
  neighbor 2.2.2.2 send-community both
  neighbor 4.4.4.4 activate
  neighbor 4.4.4.4 send-community both
  no auto-summary
  no synchronization
 exit-address-family
 !
 address-family vpnv4
  neighbor 2.2.2.2 activate
  neighbor 2.2.2.2 send-community both
  neighbor 4.4.4.4 activate
  neighbor 4.4.4.4 send-community both
  bgp scan-time 15
 exit-address-family
 !
 address-family ipv4 vrf COMPANY
  redistribute ospf 100 vrf COMPANY match internal external 1 external 2
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
ip ospf name-lookup
!
!
route-map INTERNET permit 10
 set tag 1000
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

PEy

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname PEy
!
boot-start-marker
boot-end-marker
!
```

```
enable secret 5 $1$Ep61$Lb7eJGTXUgHOZqJcJVAWG.
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host EDGE_2 192.168.0.2
ip host PEz 4.4.4.4
ip host P 3.3.3.3
ip host PECUSTOMERA2_Lo0 10.0.1.2
ip host PECUSTOMERB2_Lo0 10.0.2.2
!
!
ip vrf COMPANY
 rd 1:1
 route-target export 1:1
 route-target import 1:1
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
!
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 2.2.2.2 255.255.255.255
!
interface Loopback100
 description *** IGP VRF COMPANY ***
 ip vrf forwarding COMPANY
 ip address 10.0.0.2 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to P (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.9 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to PEz (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.13 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 description *** LINK to Edge Router 2 COMPANY ***
 mtu 4470
```

```
 ip vrf forwarding COMPANY
 ip address 10.255.0.5 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet4/0
 description *** LINK to PE CUSTOMER A2 ***
 mtu 4470
 ip vrf forwarding COMPANY
 ip address 10.255.0.25 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet5/0
 description *** LINK to PE CUSTOMER B2 ***
 mtu 4470
 ip vrf forwarding COMPANY
 ip address 10.255.0.29 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
router ospf 100 vrf COMPANY
 router-id 10.0.0.2
 log-adjacency-changes
 redistribute bgp 1 metric-type 1 subnets
 network 10.0.0.2 0.0.0.0 area 100
 network 10.255.0.5 0.0.0.0 area 100
 network 10.255.0.25 0.0.0.0 area 100
 network 10.255.0.29 0.0.0.0 area 100
!
router ospf 1
 router-id 2.2.2.2
 log-adjacency-changes
 network 2.2.2.2 0.0.0.0 area 1
 network 20.20.20.9 0.0.0.0 area 1
 network 20.20.20.13 0.0.0.0 area 1
!
router bgp 1
 bgp router-id 2.2.2.2
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 1.1.1.1 remote-as 1
 neighbor 1.1.1.1 update-source Loopback0
 neighbor 4.4.4.4 remote-as 1
 neighbor 4.4.4.4 update-source Loopback0
 !
 address-family ipv4
  neighbor 1.1.1.1 activate
  neighbor 1.1.1.1 send-community both
  neighbor 4.4.4.4 activate
  neighbor 4.4.4.4 send-community both
  no auto-summary
  no synchronization
 exit-address-family
 !
 address-family vpnv4
  neighbor 1.1.1.1 activate
  neighbor 1.1.1.1 send-community both
  neighbor 4.4.4.4 activate
  neighbor 4.4.4.4 send-community both
  bgp scan-time 15
 exit-address-family
```

```
 !
 address-family ipv4 vrf COMPANY
  redistribute ospf 100 vrf COMPANY match internal external 1 external 2
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
ip ospf name-lookup
!
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
!
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```

PEz

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname PEz
!
boot-start-marker
boot-end-marker
!
enable secret 5 $1$Opca$Uqt65ZPCb4zYgq8ivWHp20
!
aaa new-model
!
!
aaa authentication login default local
aaa authentication enable default enable
aaa authorization exec default local
!
aaa session-id common
!
!
ip cef
no ip domain lookup
ip host P 3.3.3.3
```

```
ip host PEx 1.1.1.1
ip host PEy 2.2.2.2
!
!
ip vrf COMPANY
 rd 1:1
 route-target export 1:1
 route-target import 1:1
!
ip vrf INTERNET
 rd 1:0
 route-target export 1:0
 route-target import 1:0
!
!
username cisco password 0 cisco
!
!
ip telnet source-interface Loopback0
!
!
!
interface Loopback0
 description *** MANAGEMENT PURPOSES ***
 ip address 4.4.4.4 255.255.255.255
!
interface Loopback2000
 description *** LINK to INTERNET ***
 ip vrf forwarding INTERNET
 ip address 100.100.100.1 255.255.255.255
!
interface FastEthernet0/0
 no ip address
 shutdown
 duplex half
!
interface GigabitEthernet1/0
 description *** LINK to PEx (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.6 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet2/0
 description *** LINK to PEy (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.14 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet3/0
 description *** LINK to P (MPLS CsC ISP) ***
 mtu 4470
 ip address 20.20.20.17 255.255.255.252
 negotiation auto
 mpls label protocol ldp
 mpls ip
!
interface GigabitEthernet4/0
 no ip address
 shutdown
 negotiation auto
!
interface GigabitEthernet5/0
```

```
 no ip address
 shutdown
 negotiation auto
!
router ospf 1
 router-id 4.4.4.4
 log-adjacency-changes
 network 4.4.4.4 0.0.0.0 area 1
 network 20.20.20.6 0.0.0.0 area 1
 network 20.20.20.14 0.0.0.0 area 1
 network 20.20.20.17 0.0.0.0 area 1
!
router bgp 1
 bgp router-id 4.4.4.4
 no bgp default ipv4-unicast
 bgp log-neighbor-changes
 timers bgp 5 30
 neighbor 1.1.1.1 remote-as 1
 neighbor 1.1.1.1 update-source Loopback0
 neighbor 2.2.2.2 remote-as 1
 neighbor 2.2.2.2 update-source Loopback0
 !
 address-family ipv4
  neighbor 1.1.1.1 activate
  neighbor 1.1.1.1 send-community both
  neighbor 2.2.2.2 activate
  neighbor 2.2.2.2 send-community both
  no auto-summary
  no synchronization
 exit-address-family
 !
 address-family vpnv4
  neighbor 1.1.1.1 activate
  neighbor 1.1.1.1 send-community both
  neighbor 2.2.2.2 activate
  neighbor 2.2.2.2 send-community both
  bgp scan-time 15
 exit-address-family
 !
 address-family ipv4 vrf INTERNET
  redistribute connected
  no synchronization
 exit-address-family
 !
 address-family ipv4 vrf COMPANY
  no synchronization
 exit-address-family
!
ip forward-protocol nd
!
no ip http server
!
ip ospf name-lookup
!
!
!
mpls ldp router-id Loopback0 force
!
!
control-plane
!
!
alias exec c config t
alias exec srb sh run | b router bgp
alias exec co copy run start
!
```

```
line con 0
 exec-timeout 0 0
 stopbits 1
line aux 0
 stopbits 1
line vty 0 4
!
!
end
```