Service Provider Networks

Design and Architecture Perspective

By Orhan Ergun

This Section is only a sample and complete part can be seen in the book

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First Edition

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Chapter 1

Chapter-1 Service Provider Types

Introduction

In the first chapter of the book, we will explain different Service Provider types and their businesses. When many people hear the “Service Provider” term, they immediately think about “Internet Service Provider”.

As of 2019, there are so many Service Providers which provide Internet service, but there are many other types of Service Providers that don’t provide Internet service to organizations. For example, in this chapter we will cover Content Providers; they provide content to end users/eyeballs. Also, the CDN – Content Delivery Network Provider business will be explained. They provide a distribution network to the Content Providers. Content Providers and CDN Providers don’t sell Internet service to end users or corporations. They use Internet as an underlay infrastructure to distribute the content.

New computing paradigms are emerging; these are Cloud Computing, Fog Computing and Edge Computing. We will look at Cloud Providers. Their business is not to sell Internet access to end users or corporates.
We will have a look at Edge Computing providers which provide WAF, Edge Applications, Serverless Computing, DDos Protection, Edge Firewall etc.

Some Internet Service Providers sell Internet access to other Internet Service Providers. After finishing this chapter, you will understand Backbone, Transit and Access Internet Service Providers and the business model between these providers.
There are definitely other Service Provider businesses in the IT industry but in the first version of the book, current and common Service Provider types are covered. Let the journey begin!

Broadband Service Provider

This Service Provider provides broadband services to the residential and corporate customers. Different types of broadband services such as Cable Broadband, FTTX, XDSL, BPL (Broadband over Power Line), WiMAX,3G, LTE can be provided by the same Broadband Service Provider company.

A Cable Broadband company such as Comcast has millions of Cable Broadband customers in U.S. There are also Mobile Broadband Service Provider companies such as Vodafone and AT&T which provide DSL, FTTx, which also provide mobile broadband services through 3G, LTE etc. Companies generally provide more than one type of broadband access to their customers.

Access Service Providers are mostly providing Broadband services. With broadband connection, customers can receive Internet service. They can use Internet service to access the Internet and can also create a Virtual Private Network between their offices, HQ and Datacenters by using broadband technology.

Transit Service Provider

A company which provides an Internet access to the whole Internet region is considered as a Transit Service Provider. It's also known as IP Transit Service Provider. Transit is the service of allowing traffic from a network to cross or "transit" the provider's network, usually used to connect a smaller Internet Service Provider (ISP) to the rest of the Internet.

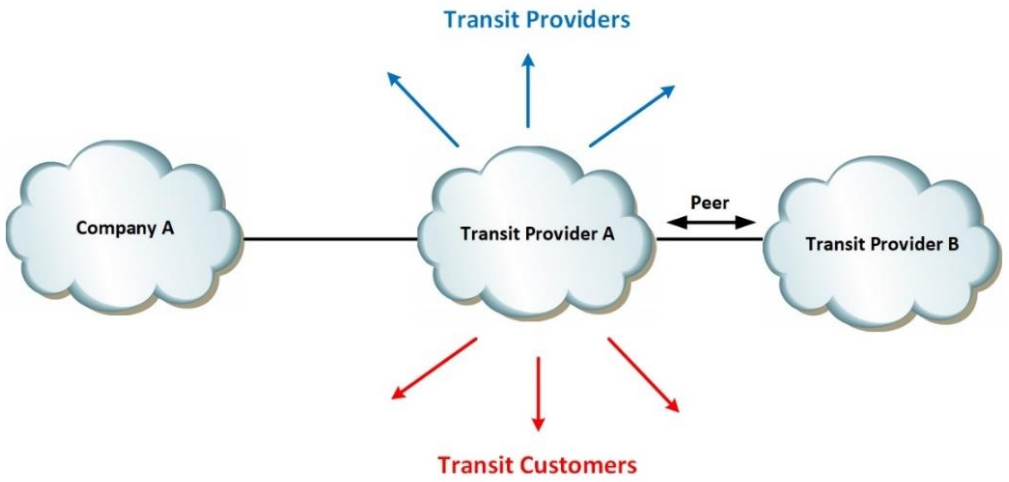

Figure 1-1 *Transit Service Provider and its connectivities*

In figure 1-1, Provider A is the Transit Provider for Company A, as it also allows Company A to access the entire Internet. In this figure, Peering connection is shown between Provider A and Provider B. This Peering connection is a Settlement Free Peering which is one of the important Interconnection models and will be explained in detail in this chapter.

Last but not least, in figure 1-1, Provider A has its own Transit Providers as well. In the Service Provider connectivity, all Service Providers have their own Transit Providers. The only exception is the Tier 1 Internet Service Provider. Tier 1 Service Providers don't receive Transit Service from any other Provider. Different Tiers and the meaning of each one will be explained in this chapter.

Transit Service Providers are the Wholesale Service Providers. They provide Internet Access to other Service Providers. A Transit Service Provider might be providing Access to the customer which will be explained next.

IP Transit, which is also commonly known as "Internet Transit" is a simple service from the customer perspective. All you have to do is pay for the Internet Transit Service and all traffic sent to the upstream Internet Service Provider is delivered to the Internet. Internet Transit is typically a measured service. The more you send or receive, the more you pay.

Internet Transit has commits and discounts. Upstream Service Providers generally offer volume discounts based on negotiated confirmation levels. So, if you commit to 10Gbps of traffic per month, you will probably get a better unit price than if you compromise with only 1Gbps of traffic per month. However, you must pay (at least) the value of the level of confirmation of traffic, regardless of how much traffic you send.

Transit contracts over the Internet have a duration and deadline. Internet Transit prices drop every year.

Access Service Provider

This type of service provider, provides last mile access to the customers. What is the definition of last mile and first mile? This is an important telecommunication term which is used in all broadband communication methods. In fact, last mile is the same as first mile. From the Service Providers perspective, the link between the Service Providers and end users is often called "last mile". From an end user's perspective, this link is called "first mile".

In any of the broadband access technologies, such as xDSL, CATV (Cable Broadband), FTTx, BPL (Broadband over Powerline), Satellite, Fixed Wireless or Mobile Broadband, the term last mile is used extensively. Last mile is the part of access network. In the last mile, we have Customer CPE (Router, switch, PC etc.), DSL modem, twisted pair copper cable and DSLAM. DSLAM is the rack which keeps so many DSL modems at the Service Provider location. Each customer side DSL modem is terminated on the modem in the DSLAM.

Chapter 2

Chapter-2 Introduction to Service Providers Network and Services

Introduction

In the telecommunication world, the operators provide Internet, Voice, Video, Cable TV, Satellite TV and/or Internet, VPN, IPTV, Cloud, Hosting and many other services to their customers. Today, most of the operators provide more than one service to increase their revenues. Almost every operator provides an Internet service as of 2019.

These operators can be any of the following types:

- Landline Phone Companies
- Cable Companies
- Cellular Phone Companies
- Satellite Companies

Service Providers provide different types of services. Some Service Providers provide broadband services, while others provide mobile services, cloud services, edge computing, VPN, Internet or hosting services. Companies generally provide more than one type of broadband access to their customers to increase their revenue.

In this chapter, we will look at different types of fixed and mobile based broadband services such as XDSL, FTTX, Cable Broadband, Fixed and Mobile Satellite, Wireless Internet Service and Mobile Broadband LTE (Long Term Evolution).

Broadband Services

Broadband signals compared to narrowband signals have much more band in the frequency spectrum. Thus, the term is referred as broadband. Higher band in the frequency spectrum allows faster data communication. Early Dial-up modems (over telephone lines) worked based on narrowband, thus they only provided voice communication and slow data speeds such as 56kpbs.

Broadband allows much higher data speeds such as 1Gbps or even more. DSL, FTTX, Cable Broadband, 3G, 4G Mobile Broadband are the examples of broadband technologies. These technologies will be covered in detail later in this chapter.

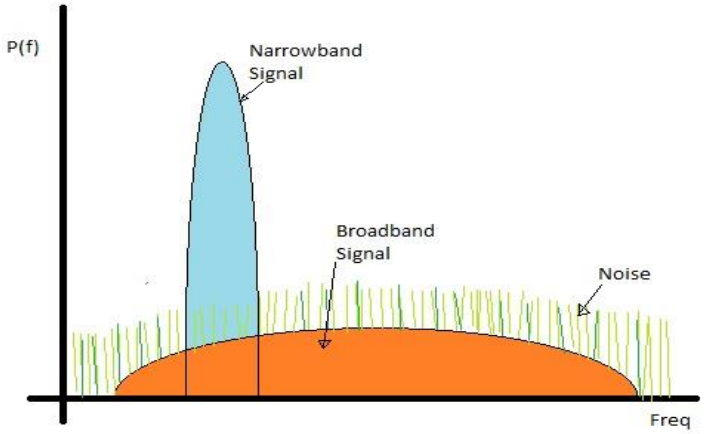

Figure 2-1 *Broadband*

Carrier and ISP are very commonly used terms in the industry. There is a difference between them.

- **Carrier** is the company that owns the phone lines and maintains them.
- **Service Provider** is the company that is responsible for making sure that the services (such as voice, VPN and Internet Service) are functioning properly.

Sometimes the Service Provider owns its hardware that provides the technical directions to the carrier, other times they manage the carrier's hardware. The difference between Carrier and Service Provider is similar to FedEx and EBay. One is bringing the service to you; while the other is selling those goods to you.

In this chapter, various Broadband Technologies will be explained in detail. Broadband Technologies can be categorized as Fixed or Mobile Broadband Technologies.

Chapter-3 Service Provider Physical Connectivity and Transport Network

Introduction

Service Providers use different types of physical connectivity as the transport to connect the customers to their network. Customers such as Residential Customers, Business/Corporate Customers, etc. (that have been explained in the previous chapter), all connect to the Service Provider network through many different types of physical connectivity layer, that will be explained in detail in this chapter.

Also in this chapter, transport network basics such as Fiber optic, Microwave, Comparison of Fiber and Microwave, SONET/SDH, WDM and Dark fiber will be covered. Terrestrial and Sub Marine/Undersea Cable Systems and the components of these systems will be shared.

Fiber Optic

Fiber-Optic cables carry information between two places using entirely optical (light-based) technology. A fiber-optic cable is made up of incredibly thin strands of glass or plastic known as optical fibers; one cable can have as few as two strands or as many as several hundreds. Each strand is less than a tenth as thick as a human hair and can carry something like 25,000 telephone calls, so an entire fiber-optic cable can easily carry several million calls.

Total Internal Reflection

Fiber technology works based on total internal reflection. The basic functional structure of an optical fiber consists of an outer protective cladding and an inner core through which light pulses travel.

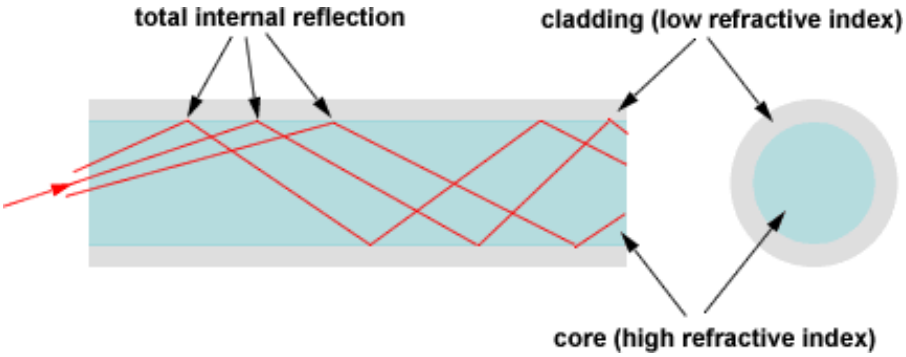

Figure 3-1 *Total Internal Reflection – How Fiber works*

The difference in refractive index of the cladding and the core allows **total internal reflection** in the same way as happens at an air-water boundary, as shown in figure 3-1. Thus, fiber optics use total internal reflection.

Figure 3-2 *Total Internal Reflection can be seen at the air-water boundary*

Chapter 4

Chapter-4 Service Provider Physical Locations

Introduction

In Service Provider networks, there are physical locations which provide many different functions. These locations can be CO (Central Office), POP, Datacenter, Colocation Centers, Meet-me room etc. Understanding what kind of services these locations can provide, how they are connected to the rest of the network, and what are the IT functions and services that these places provide, will be the topics of this chapter.

The terminology of these locations can change based on the geography. In different parts of the world, same functional places can have different names. For example, in U.S, telecom facility which provides the last mile access to the customer is called CO (Central Office), but in Europe it is called as Exchange or Telephony Exchange.

Naming convention is not only changed based on the country, as different providers might call these places differently. For example, for the Core POP location, different provider network engineers might call it, Backbone POP, Main POP, or Tier 1 POP.

CO (Central Office)/Telephony Exchange

CO is a U.S based term. In the rest of the world, it is commonly used as Telephony Exchange or Public Exchange. (It shouldn't be confused with Public Exchange which we will cover in the IXP topic later in this chapter).

Central Office is a telecom facility where subscriber's local loop (last mile connection) is terminated. Broadband termination equipment such as CMTS, DSLAM, OLT, PSTN and other Voice switching equipment are placed in the Central Office. Many Service Providers use the Access POP term rather than CO (Central Office).

Figure 4-1 *Subscriber Copper Lines at the Central Office*

POP – Point of Presence

POP is a place where communication services are available to subscribers. Internet Service Providers have multiple POPs in different geographic locations, so subscribers can connect to a location closest to them. POPs can be co-located at the Service Provider's central office (CO). Central Office term is mostly used in U.S and Europe. Access POP is the most commonly used term for the Central Office.

Generally, base stations, modems, switches, routers, servers, security and voice appliances are located in the POP sites. POP sites are the demarcation point between customer and Service Provider. POPs can be located at the Internet Exchange Points (IXP will be covered in the Interconnection chapter) as well as the Colocation Centers. POPs can include a meet-me-room which will be explained in this chapter.

Service Providers may classify their POP locations based on speed, hierarchy, technology used in the POP and so on. Earlier it was a trend to classify the POPs with their speeds such as Gigabit POPs, Terabit POPs and so on, but this is not used anymore. POPs are classified mostly based on their hierarchy such as Access POP, Distribution POP/Aggregation POP and Core/Backbone POP.

Chapter 5

Chapter-5 Service Provider Modules - The Big Picture

Introduction

Service Provider's provide many different types of services. Their services are categorized in many different ways.

One way of categorization is based on their customer profile:

Residential customers are apartments, multi-floor buildings which generally don't require higher speed connections.

Business/Corporate customers are smaller Service Providers, small medium Businesses and Enterprises. These customers require higher bandwidth, between 10Mbps to 10s of Gigabit per second.

Another way of categorization is based on the service as well. If end user devices are stationary, the service is called Fixed or wired. If end user devices are not stationary, then the service is called Mobile service. In this chapter, both service categorization (Fixed and Mobile services) and customer profile categorization (Residential and Business Customer service) will be explained. In Chapter 7 and 8 we will discuss a Fictitious Service Provider Company. In order to understand and create a Service Provider network from scratch, it is important and necessary to understand the Service Provider network environment. Thus, this chapter will cover many different parts of the Service Provider networks. Also, before starting the logical level, protocol and technical discussions about the Service Provider networks, it is necessary to understand each module and the physical layout of the Service Provider's network.

In figure 5-1 (Service Provider Services) , the connectivity , names of the nodes in the specific service, common topologies in each of the services and briefly the Service Provider networks with sufficient detail is shared. Some operators provide different types of Access connectivity such as Public WIFI, BPL (Broadband Over Power Line), Satellite and also other types of connectivity, but in this book we tried to cover the most commonly deployed Access technologies used in real Service Provider networks.

In figure 5-1, there are 12 modules, which are listed as bellow. Each of these modules will be explained in this chapter.

1. Core/Backbone Network
2. Datacenter and Server Farm Modules
3. Border/IGW Layer
4. XDSL Access
5. FTTX Access
6. Cable Access
7. Mobile Broadband
8. Fixed Broadband Wireless
9. WiMAX
10. National Peering
11. International Peering and Transit
12. Business/Corporate Customers

Core Layer Module

The Core layer is the center module of the network, which has the responsibility of connecting all the modules of the Service Provider network together. The traffic between all modules are passed through the SP Core layer. Core/Backbone layer should have high capacity and there are not much protocol, technology and control plane policy found in this layer. It should be designed simple and with high capacity and redundancy.

The Core Layer provides connectivity nearly between each of the Service Provider Modules which are shown in the above list and provides connectivity between different regions of the Service Provider.

Chapter 6

Chapter-6 Service Provider Interconnections and Peering

Introduction

Peering is a BGP session between two Routers. When different companies have Peering with each other, they exchange network traffic over the peering session. There are three reasons to have BGP peering on Internet:

- Company wants to receive an Internet service
- Company wants to sell an Internet service
- Two companies exchange their customer prefixes and exchange network traffic but don't pay to each other, which is called Settlement Free Peering.

BGP is important, but this is not the topic of this chapter. It is important to understand the business models between the companies on the Internet.

- Who peers with whom?
- Which company pays to who?
- Why they peer or receive a service?

Service Providers sell Internet connectivity. Mostly they purchase Internet service from each other. Enterprises peer with Service Providers as well. From this chapter, you will be able to understand Settlement Free Peering, IP Transit, Paid Peering, Remote Peering and any "Peering" related topics. When you finish this chapter, you will not use the term "Peering" only as BGP neighborship, instead this term will remind you about Settlement Free Peering or Settlement Free Interconnection.

Settlement Free Peering

Settlement Free Peering is the main topic of this chapter but different variations of Settlement Free Peering such as Paid Peering and Remote Peering will be explained as well.

Settlement Free Peering is also referred as Settlement Free Interconnection and here onwards, to make it short, SFI term will be used. SFI is an agreement between different Service Providers. It is an EBGP neighborship between different Service Providers to send BGP traffic between them without paying to the upstream Service Provider. Settlement Free Interconnection - SFI is a way of life for some Internet networkers. It is how the business of the Internet works.

SFI is both a business and technical relationship between two networks. It is an agreement where the networks concede to trade traffic between each other's customers, without payment or without settlement. There are multiple steps for creating an SFI relationship. There are also many ways to walk down those steps. Majority of traffic on the Internet flows over PNIs (Private Peering). The Private Peering concept will be explained later in this chapter.

Without private connection based SFI, the Internet would be centralized across intermediate platforms. Risk would be higher. Performance could be lower. Costs would be substantial. We generally reduce the risks and costs of the interconnection.

SFI relationships require more than just knowledge of how BGP works. Business realities must be understood and mixed skillfully into the recipe. This includes technical aspects to ensure the proper outcome. Simply throwing fiber over a cage wall worked 25 years ago.

Today, lawyers, accountants, project managers and performance testers are stakeholders. They are part of the conversation. They add collective value to the business decision. As a collective, they ensure that an agreement is as comprehensive and practical as possible. Not all SFI agreements are created equal. Many are based on handshakes or email.

There are three primary relationships between the companies on Internet. The Customer, Peer and Provider as it was briefly mentioned above.

Business relationships between the networks:

1. **Provider:** Typically, someone who is paid and has the responsibility of routing packets to/from the entire Internet.

2. **Customer:** Typically, someone who pays a provider with the expectation that their packets will be routed to/from the entire Internet.

3. **Peers:** Two networks that get together and agree to exchange traffic between each other’s networks, typically for free. There are generally two types of peering: public and private. Both will be explained in this session.

Chapter 7

Chapter-7 ATELCO National Internet Service Provider Design

Introduction

ATELCO is a leading Telecommunication Service Company in Middle East. They have nationwide backbone infrastructure in fictitious country Greenland. They have around 11 million customers in the country; most of them are residential customers.

They have Business/Corporate customers from different fields such as other Internet Service Providers, Hosting Providers, Airports, Banks, Hospitals, Holding Companies, Newspapers, Application Providers, Content Providers, Universities, Hypermarkets, Government Companies etc.

1. Northern Region
   This region collects all customer traffic from the North part of the country and consists of around 100 Access POP locations, more than 10 Aggregation POP locations and 2 Core POP locations. Also, ATELCO has 1 Internet Gateway POP location, placed in one of the two CORE POP locations in a major city. At the Internet Gateway location, they have shared services routers, Internet Settlement Free Peering connections, IP Transit Provider termination and many cache servers of the content providers.

   The Northern region also serves as a backup for all the other regions, so in case of any Internet outage in other regions, it will provide Internet connectivity to customers in those regions.

2. Southern region
   This Region collects all customer traffic from the South part of the country and consists of around 100 Access POP locations, more than 10 Aggregation POP locations and 2 Core POP locations. Also, ATELCO has one Internet Gateway POP in the Southern region, placed in one of the two CORE POP locations in a major city. At the Internet Gateway locations, they have shared services routers, Internet Settlement Free Peering connections, IP Transit Provider termination and many cache servers of the content providers.

3. Eastern region
   This region collects all customer traffic from the East part of the country and consists of around 100 Access POP locations, more than 10 Aggregation POP locations and 2 Core POP locations. ATELCO in the Eastern region has one Gateway POP location, residing in one of the two CORE POP locations where they have shared services routers, Internet Settlement Free Peering connections, IP Transit Provider termination and many cache servers of the content providers.

4. Western region
   This region collects all customer traffic from the west part of the country and consists of around 100 Access POP locations, more than 10 Aggregation POP locations and 2 Core POP locations. ATELCO has one Gateway POP location in the Western region, residing in one of the two CORE POP sites where their shared services routers, Internet Settlement Free Peering connections, IP Transit Provider termination and many cache servers of the content providers exist.

As a summary of ATELCO's POP locations in the 4 regions, ATELCO only has one Internet Gateway POP location in each region, but various numbers of Access, Aggregation and Core POP locations. In figure 7-2, ATELCO's POP interconnections are shown.

Chapter 8

Chapter-8 ATELCO Network - Design Detail Explanations

Introduction

During the scenario, many information about ATELCO network was provided. In this section, detail explanation will be provided about their network design and also many real-life ISP network design examples will be shared with the readers.

Many information and the topologies which were shared in the previous chapter about ATELCO's network will be repeated here as a reminder. The reason of having this chapter as a separate chapter in the book is to keep the previous chapter short and understandable. So we will provide more detail in this chapter about the current design of ATELCO and discuss different alternative designs which other Internet Service Providers have in the World.

After this section, you will understand what kind of services other Internet Service Providers provide as well, what are the current trends, how they design and implement the technologies and the protocols on their network along with pros and cons of the available methods that are used.

In each section of this chapter, we will share the text which was given in the previous chapter during ATELCO's design review.
We will discuss the alternative design options, pros and cons of the current design of ATELCO and we will have a look at the future roadmap for ATELCO by keeping the Evolving Technologies in mind.

In the previous chapter, it was given that ATELCO is a leading telecommunication services company in Greenland (A fictitious country). They have nationwide backbone infrastructure in

fictitious country Greenland. They have around 11 million customers in the country; most of them are Residential (fixed and mobile broadband) customers.

11 million customers for many countries is very normal as the subscriber numbers. In fact, there are many Operators that have more than 11 million customers in their country.

Out of 11 million customers, most of them are residential customers. ATELCO has Enterprise Customers as well. They haven't shared the number of Enterprise customers but it was given in the previous chapter that ATELCO terminates Enterprise Customers at the Pre-Aggregation Layer. We will discuss Service termination for the Residential and the Enterprise customers in detail later in this chapter.

We will cover this chapter in many parts. It will start with the Physical Infrastructure of ATELCO, secondly Logical Architecture will be shared. In the Logical Architecture section, IP/MPLS, IGW and Global Network Connectivity will be covered. After that, Services and last but not least Technologies and the Protocols in ATELCO will be explained in great detail.

ATELCO Physical Network

Regional Connectivities of ATELCO Network

We will start to introduce ATELCO's network. ATELCO has four regions in the country called Greenland. Internet Service Providers can be categorized as follow:

- Nationwide
- Regional (which is more local)
- International

Internet Service Providers which provide nationwide service, generally divide the country to different regions. Some operators use the term 'Regional Provider' for those who provide services to more than one country. So, the definition of 'Regional Provider' is either the Provider who serves a specific part of a country or provides a service to more than one country. Definitions might change based on the place in the world.

In U.S, regional provider mostly refers to one which provides the service in a part of the country, in Europe; Regional Provider refers to one which provides the services to more than one country.

As per Author's experience, in general, ISPs divide the country as three, four and even five regions (many cities inside each region) and manage the traffic flow, deploy the physical devices, start the services and connect the Internet Interconnections based on these regional arrangements.

Operators which divide the country to three regions have East, West and Central regions. They do it for optimal routing which provides better resource utilization, so leads to reduced costs. Each regional traffic reaches to the Internet from their local connectivity. So, the East Region users

Chapter 9

Chapter-9 Evolving Technologies in the Service Provider Networks

Introduction

Service Providers encounter various challenges to provide next generation services to accommodate fast-paced demands of the market. Furthermore, by the introduction of 5G, video traffic growth, IoT and cloud services, combined with services requiring ubiquitous connectivity from Access to Core, Service Providers require unprecedented level of flexibility, elasticity and scalability in the network infrastructure.

In this chapter, we are going to introduce new approaches to design highly scalable Service Provider networks by means of new technologies such as Segment-Routing (SR), Fast Reroute with TI-LFA, PCE, Egress Peer Engineering, EVPN, PBB-EVPN, BGP in Massively Scalable Datacenter, NFV and Multicast BIER.

Service Provider Design Using Segment Routing

Service Providers must choose a very flexible design that meets any to any connectivity requirements, without compromising in stability and availability. In the divide-and-conquer strategy in which the Core, Aggregation, and Access domains are partitioned in different IGP domains, formerly used by Unified/Seamless MPLS, and as presented previously in the ATELCO Scenario in the book, it reduces the size of routing and forwarding tables within each domain, so it provides better stability and faster convergence.

Traditionally, Unified MPLS used LDP or RSVP-TE to build LSP within the IGP domain and used BGP-LU (RFC 3107) for inter-Domain LSPs. Segment Routing reduces the number of required protocols in a Service Provider network by adding simple extensions to IGP protocols such as ISIS or OSPF that can assign and distribute labels to build LSP within each IGP domain. This enables a device inside an Access, Aggregation, or Core domain to have reachability through intra-domain SR LSPs to any other device in the same region. In the next pages, we will see in some scenarios that it is better to eliminate BGP-LU for faster convergence and simplicity of the network. Programmability based network architecture based on Segment-Routing will add SLA awareness into the network and provides better network scaling.

Segment Routing Introduction

Based on the definition of IETF (RFC 8402), Segment Routing (briefly SR) leverages the source routing paradigm. This definition is the most notable feature of SR that everything happens in Head-end node based on an ordered list of instructions, called “segment”. A segment can be local or global within the SR domain and often referred as Segment Identifier (SID). SR can work on MPLS dataplane. A segment is encoded as an MPLS label and ordered segments are encoded as a stack of labels.

Processing of segments starts from top and after completion of the top-most segment, it is popped from the stack. Also, SR can work on IPv6 data plane with the new type of routing header. A segment is encoded as an IPv6 address and ordered segments are encoded as a stack of IPv6 addresses in the routing header. Segment Routing reduces the number of protocols needed in a Service Provider Network. Simple extensions to traditional IGP protocols like ISIS or OSPF, provide full Intra-Domain Routing and Forwarding Information over a label switched infrastructure, along with Fast Re-Route (TI-LFA) capabilities.

This is an enhancement in comparing SR with Label Distribution Protocol (LDP), that SR capable IGP node advertises segments for its attached prefixes and adjacencies through IGP header instead of using another protocol.

Service Provider Networks - Design Architecture Perspective

About this book

- This book will give you a High Level of overview of the Service Provider Network Design and Architecture.
- It talks about the unique aspects of Service Provider networks, different types of Service Providers and the business relationships between them.
- It covers the Service Providers services, different access last mile offerings and transport networks, and their subscribers and services.
- Technical explanation about different types of Fixed and Mobile network services and the Service Provider physical locations are also explained.
- You will see the Big Picture of Service Provider Networks.

After understanding the Service Provider Concepts and Technologies, a fictitious National Service Provider network, named ATELCO will be introduced, to give you a more view of the technologies, protocols, services and end to end traffic flow in detail. And at last the Evolving Technologies used in Service Providers and Massively Scale Datacenters will be seen.

About the Author

Orhan Ergun, CCIE/CCDE Trainer, Author, Network Design Advisor and Cisco Champion 2019. Orhan Ergun is award winning Computer Network Architect, CCDE Trainer and Author. has well known industry certificates CCIE #26567 and CCDE #20140017. has more than 17 years of networking experience and has been working on many medium and large-scale network design and deployment projects for Enterprise and Service Provider networks.He has been providing consultancy services to African, Middle East and some Turkish Service Providers and Mobile Operators for many years. Orhan has been providing Cisco network design training such as CCDE, Pre-CCDE, Service Provider Design and many Advanced technologies for many years, and created best CCDE Training Program to share his network design experience and knowledge with the networking community.Orhan is sharing his articles and thoughts on his blog www.orhanergun.net. All the training and consultancy services related information can be found from his website. Orhan has a Training and Consultancy company located in Istanbul, Turkey.

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