Enterprise Network WAN Interconnection

Foreword

- After years of development and evolution, the Internet has undergone significant changes. In the past, the Internet was centered on networks, and there were few Internet applications. As a major part of the network, the WAN takes the most important position on networks. However, the rise of cloud computing fully unleashes the potential of applications, and the Internet gradually becomes application-centric.
- Traditional WAN interconnection focuses on connectivity, and there is no strict requirement for QoS or SLA. How can WANs evolve to meet requirements of the application-centric Internet?
- After completing this course, you will be able to understand the development trend of WAN technologies and how to cope with the application-centric Internet.

Objectives

- Upon completion of this course, you will be able to:
  - Describe the challenges of WAN interconnection in the cloud era.
  - Illustrate basic SDN concepts.
  - Explain basic concepts of SD-WAN.

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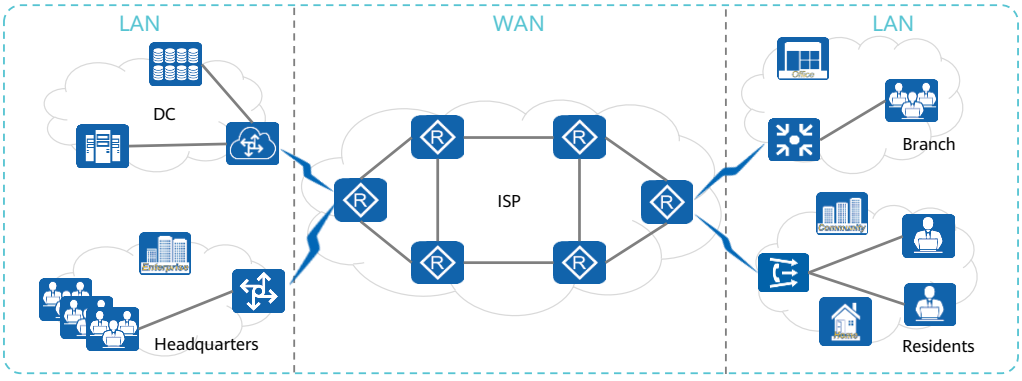
2. Challenges Faced by Enterprise WAN Interconnection
3. Emergence of SD-WAN

What Is a WAN?

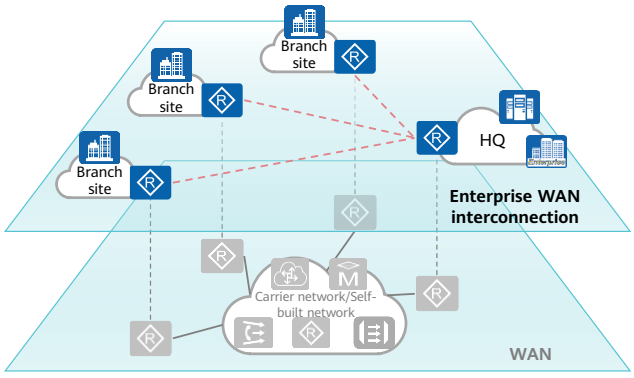
- Wide Area Network (WAN) provides interconnection services between different regions, cities, and countries. A WAN usually spans a long distance (dozens of kilometers to thousands of kilometers). To meet long-distance transmission requirements of a WAN, optical fibers are often used as the interconnection media.



- LAN
  - A local area network (LAN) is a computer network that connects computers, peripheral devices, databases, and other devices in a limited geographical area (such as a campus, factory, or organization) within thousands of meters.
- WAN
  - WANs provide wider coverage than LANs and metropolitan area networks (MANs). The communication subnet of a WAN mainly uses the packet switching technology. The communication subnet of a WAN can use the public packet switching network, satellite communication network, and wireless packet switching network to interconnect the LANs or computer systems in different areas for resource sharing.
  - The Internet is the largest WAN in the world.
- Relationship between the LAN and WAN:
  - A LAN is located in an area, whereas a WAN spans a larger area. For example, the headquarters of a large company is located in Beijing, and its branches are distributed all over the country. If the company connects all its branches through a network, a branch is a LAN, and the company network is a WAN.
  - Typical WAN rates range from 56 kbit/s to 155 Mbit/s. Currently, 622 Mbit/s, 2.4 Gbit/s, and even higher rates are available. The transmission delay ranges from several milliseconds to hundreds of milliseconds (when satellite channels are used).

WAN and Enterprise WAN Interconnection

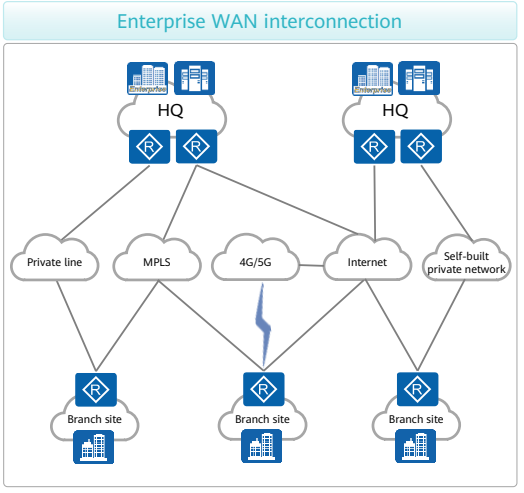
- Enterprise WAN interconnection refers to the interconnection between nodes at different levels, such as the headquarters, data centers (DCs), branches, fixed offices, and mobile offices.
- Generally, enterprise WAN interconnection depends on a WAN built by a carrier or the self-built WAN.



- Enterprises that cannot build their own WANs usually lease ISP lines and use VPN or private line technologies to build enterprise WANs.
- Enterprises that have WAN capabilities do not need to lease ISP lines except for Internet services.

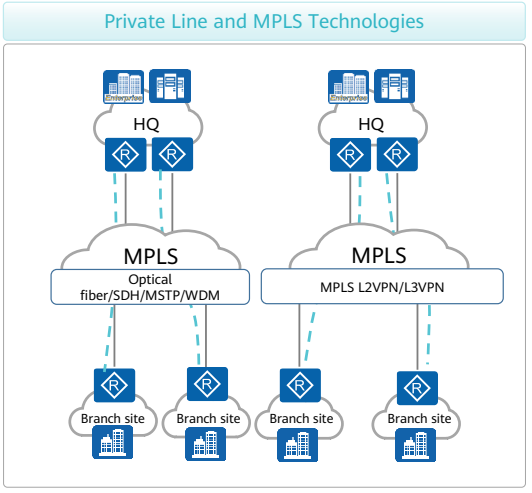
Main Enterprise WAN Interconnection Modes

- Generally, enterprise WANs can be interconnected in the following modes:
  - Carriers' MPLS or private lines are used to connect regional networks. This mode is applicable to enterprises with high SLA requirements and is expensive.
  - The carrier Internet + VPN technology is used for connection. This mode is applicable to small- and medium-sized branches that do not have high SLA requirements.
  - Carriers' point-to-point (P2P) private lines are used to implement cross-city or cross-border connections. This mode is mainly used for connections between DCs, headquarters, or important branches, and is expensive.
  - Industries such as electric power and transportation have network connections through self-built private lines.
- Enterprise WANs usually use a combination of the preceding connection modes.



Enterprise WAN Interconnection Technologies - MPLS and Private Line

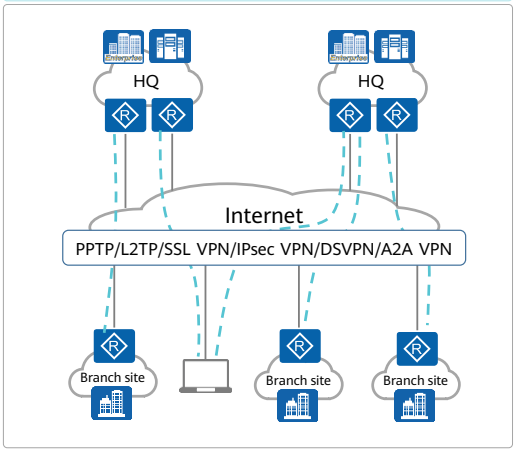
- To ensure network reliability and security, enterprises lease MPLS or private lines from carriers when constructing enterprise WANs.
  - Private lines are expensive, but data is carried on dedicated lines, ensuring service quality and security.
  - Leasing MPLS lines from carriers is cheaper than private lines and can ensure service security. However, service reliability is not as good as that of private lines.
  - A small number of enterprises (such as transportation and electric power enterprises) have the capability of deploying optical fibers and can build their own backbone networks. For these enterprises, the cost of using MPLS or private lines is very low.



Enterprise WAN Interconnection Technologies - Internet and VPN

- With the development of the Internet, some enterprise services can be carried over the Internet.
- The Internet is open, so VPN technology is used to provide secure and reliable connections.
- Virtual Private Dial-up Network (VPDN) technologies, such as Point-to-Point Tunneling Protocol (PPTP), Layer 2 Tunneling Protocol (L2TP), and Point-to-Point Protocol over Ethernet (PPPoE), allow terminal users or branches to dial up to the carrier network or headquarters network.
- Internet Protocol Security (IPsec) and Generic Routing Encapsulation (GRE) technologies are used to build networks between enterprise branches or between enterprise branches and the headquarters.
- To simplify IPsec configuration on large-scale networks, technologies such as Dynamic Smart VPN (DSVPN) and Any to Any (A2A) VPN have been developed and widely used.

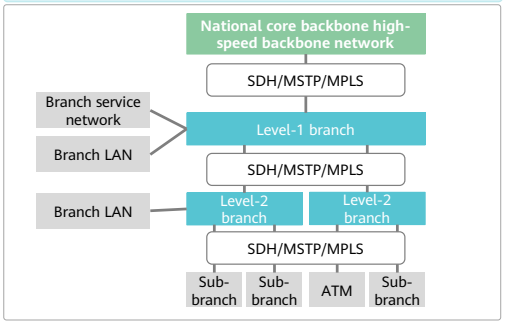
Internet and VPN technologies



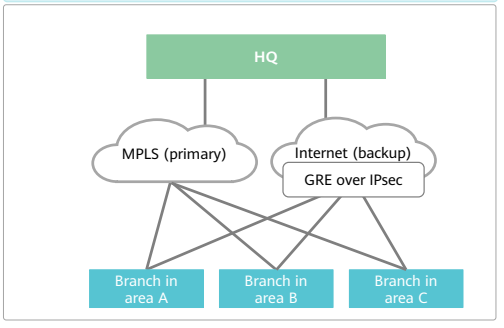
Common Application Scenarios of Enterprise WAN Interconnection

- Enterprise WAN interconnection needs to be deployed based on enterprise requirements. For example, in the financial industry, most enterprises lease private lines or MPLS lines to ensure reliability and security. Considering network costs, other enterprises usually lease MPLS lines as primary lines and Internet+VPN lines as backup lines.

WAN interconnection in the financial industry



WAN Interconnection for a wine enterprise



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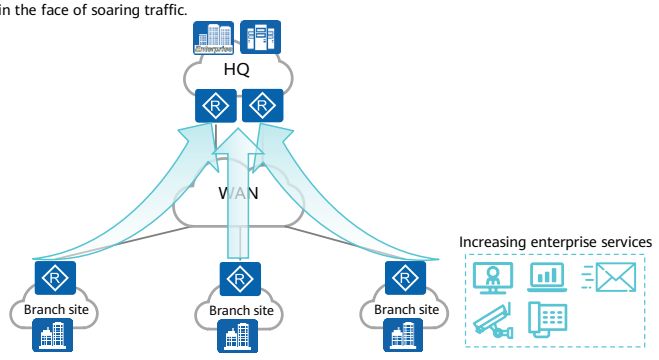
Challenges to Enterprise WAN Interconnection Brought by Cloud Computing

- Before cloud computing is introduced, there are a few network applications, and the network service quality can be ensured only by expanding the bandwidth. Service traffic does not need to be managed in a refined manner. The Internet is mainly built based on the network.
- With the advent of cloud computing, the number of network applications is greatly increased. As a result, it is difficult for enterprises to strike a balance between line prices and service quality in the face of soaring traffic.

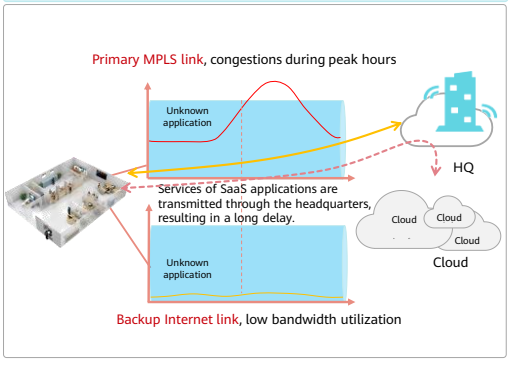


- To ensure the reliability of some key services on the cloud, enterprises usually lease carriers' private lines to carry these services. However, with the increase of enterprise services, enterprises face the following problems:
  - A large amount of bandwidth is required to migrate services to the cloud. High-bandwidth private lines, especially cross-province and cross-border private lines, are expensive.
  - If the Internet is used to build VPNs, the cost can be reduced, but the reliability of key services cannot be ensured.
  - If key services need to be carried on private lines and common services need to be carried on Internet, the configuration is complex and difficult to control.

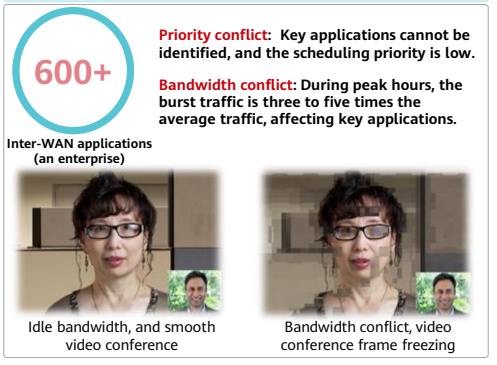
Challenges to Enterprise WAN Interconnection Brought by Multiple Services

- Enterprises have poor service traffic awareness capabilities and cannot effectively guarantee key services. In addition, the monitoring capability of service traffic is insufficient, and service traffic cannot be quickly adjusted.

No application visibility; difficult traffic scheduling



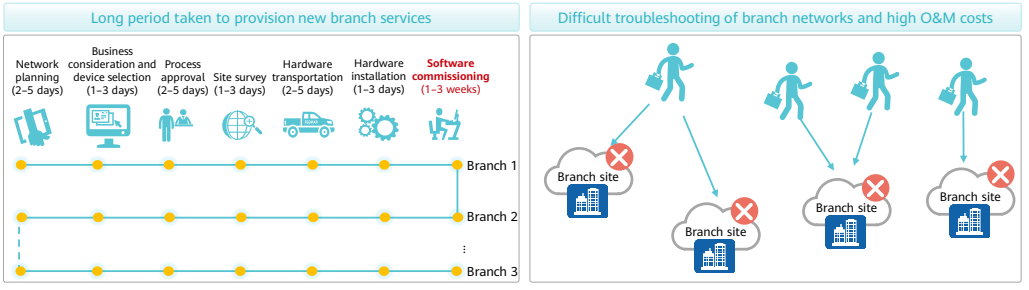
Key services such as voice, video, and SaaS are difficult to manage.



- Existing traditional technologies cannot effectively monitor the actual traffic of services.
  - Traditional network management technologies (SNMP) can only monitor interface bandwidth usage.
  - The interface usage cannot be monitored based on service applications, and the quality of key services cannot be detected.
  - Service applications cannot be detected, and therefore services cannot be precisely controlled.

Challenges to Enterprise WAN Interconnection Brought by a Large Number of Branches

- With the development of companies, there will be more and more cross-city, cross-province, and cross-border branches. As a result, companies face the following problems in branch network management:
  - Too many branches result in high O&M costs.
  - It takes a long time to provision new branch services.
  - It is difficult to rectify faults on branch networks.



- Software-defined networking (SDN) technology can be used to address the challenges brought by existing services to enterprise WANs.

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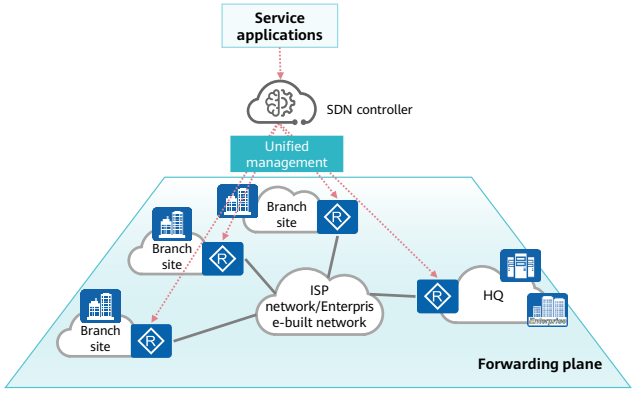
What Is SDN?

- SDN decouples the forwarding plane, control plane, and service applications, allowing networks to be quickly adjusted and new services to be quickly deployed in the same way as IT applications.



SDN Advantages

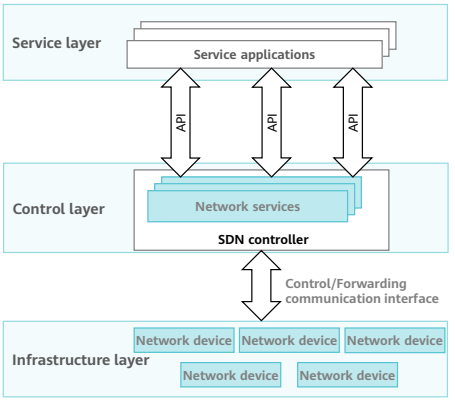
- SDN reconstructs the network architecture, and is not a new feature or function.
- SDN overcomes the disadvantages of traditional networks.

Disadvantages of traditional networks	Advantages of the SDN network
• The network architecture is distributed. A network device is a closed system consisting of hardware, an operating system, and network applications, and control and data forwarding functions are tightly coupled. • Disadvantages: ▫ Low network flexibility ▫ Complex network protocols ▫ Heavy dependency on network device vendors ▫ Difficult O&M management	• SDN provides a new network architecture that separates the network control function from the forwarding function and implements programmable control. • Advantages: ▫ Network virtualization ▫ Network automation ▫ Rapid service provisioning ▫ Openness and programmability

SDN Overview | SD-WAN Characteristics | Core Values of SD-WAN

SDN Architecture

- Service layer
  - The service layer is the interaction interface at the top of the SDN architecture. It consists of various network application services and is responsible for understanding users' service requirements and orchestrating network services based on user requirements.
- Control layer
  - The control layer is the brain of SDN. It opens abstracted network functions and services to the application layer through northbound interfaces and controls the forwarding behavior of underlying network devices through southbound interfaces.
- Infrastructure layer
  - The infrastructure layer can be regarded as the core of the SDN architecture and consists of various common network devices. These network devices forward traffic based on the policies delivered by the control layer.



- The SDN network architecture is provided by the Open Network Foundation (ONF).
- The SDN architecture can be divided into three layers from top to bottom: service layer, control layer, and infrastructure layer.

Characteristics of SD-WAN: Automatic Network Orchestration

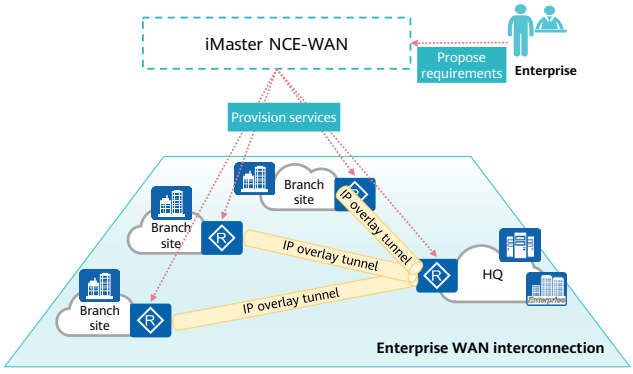
- Service- and intent-orientation, implementing network orchestration and automatic provisioning.

Traditional network

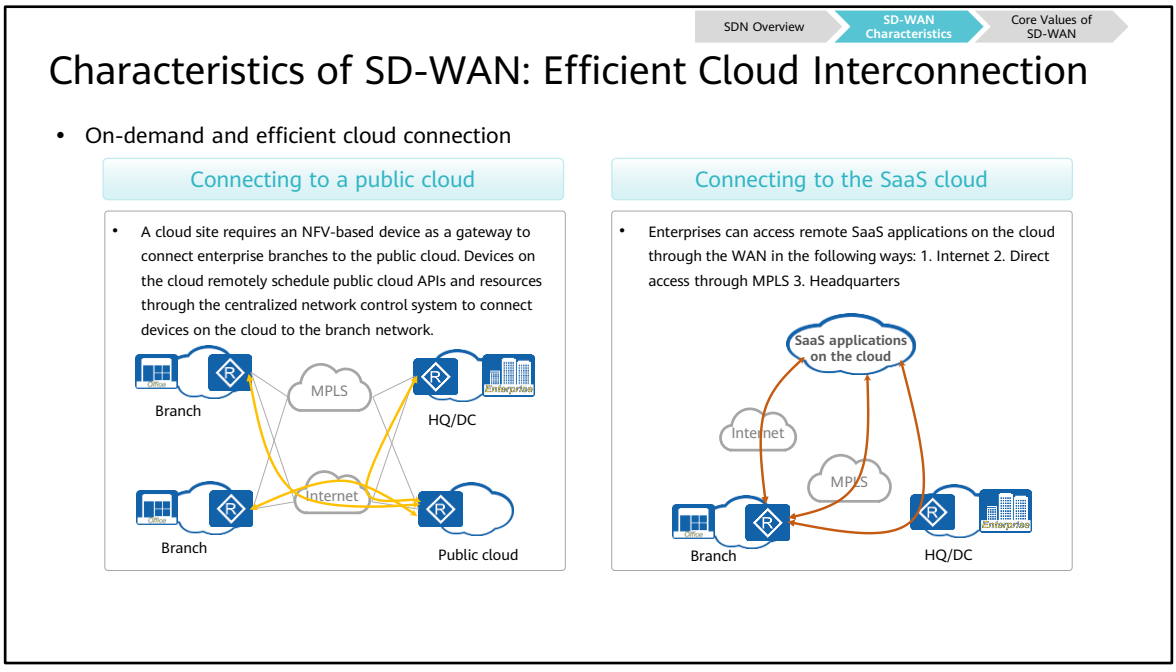
- Traditional network service provisioning requires professional network engineers to perform planning, configuration, and O&M, and then run commands or use the NMS software to configure devices one by one based on the planned services.

SDN network

- The SDN network uses a centralized network control system to abstract, orchestrate, and automatically provision network services on demand. It shields technical implementation details of the network and opens only service-oriented interfaces and parameters to users.



- For example, an enterprise wants to connect multiple branches through the headquarters. Traditionally, network parameters, such as interfaces, IP addresses, routing protocols, security, and VPN, are manually configured on each branch device. If there are 100 sites, devices need to be configured one by one. In addition, you need to configure special routes for the headquarters to forward all traffic. The entire process is complex and requires operators to be familiar with network technical details such as switching and routing. Service provisioning is slow and manual operations are prone to errors.
- In SD-WAN, assume that a centralized network control system serves as the control center of the network and can manage all branch devices. The network control system, as the brain of the network, displays a network connection operation primitive that can be understood by a non-network professional user. For example, a user's instruction is to enable 100 sites, and the headquarters site is used for interconnection, and the user does not need to enter network-level parameters. After receiving the request, the network control system automatically translates the original network connection requirement into traditional network configuration operations that can be understood by network devices, that is, operations such as routing and VPN that are manually performed in the traditional method. Then it further transmits the operation to the devices at the branch site, thereby implementing automatic provisioning of network services. The entire network service provisioning process is automatically completed by the network control system, which effectively lowers the network skill requirements of users and reduces network operations. In addition, automatic conversion of the network control system is not error-prone, which greatly improves the WAN service provisioning efficiency and user experience.

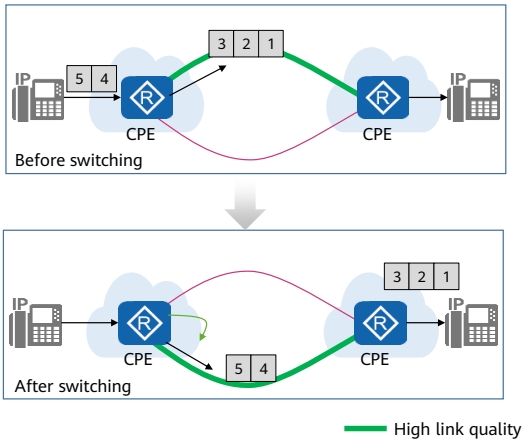


- With the advent of the cloud era, enterprise WANs need to open the traditional closed network architecture and flexibly connect various cloud resources. Cloud resources closely related to enterprise WANs include IaaS basic cloud services and SaaS cloud applications. With the popularity of public clouds, more and more enterprises are considering migrating their IT systems to public clouds. An enterprise's system in the public cloud can be considered as a special branch site, that is, a cloud site. A cloud site also requires a device that functions as a gateway to connect enterprise branches and the public cloud. Because the device is deployed on the cloud, the device must be based on NFV. Devices on the cloud need to be quickly created and connected to enterprise branch sites in real time. Therefore, a centralized network control system is required to remotely schedule public cloud APIs and resources, automatically start devices on the cloud, and connect the public cloud and branch networks.
- To access SaaS applications efficiently, SD-WAN needs to have the capability of optimizing SaaS access paths. When an enterprise accesses a remote SaaS application on the cloud through the WAN, multiple paths may be available, for example, access through an Internet, an MPLS network, or the HQ. A branch needs to be capable of perceiving network Service Level Agreement (SLA) quality of each optional path in real time, with the help of the centralized network control system. It can adjust and select the optimal SaaS access path in real time.

SDN Overview | SD-WAN Characteristics | Core Values of SD-WAN

Characteristics of SD-WAN: Intelligent Traffic Steering

- Intelligent traffic steering, ensuring application experience
  - The introduction of hybrid WAN provides multiple WAN links for enterprise service traffic.
  - Different WAN links have different network quality. High-value applications are preferentially transmitted through high-quality WAN links. In this case, route selection based on application SLA needs to be implemented.

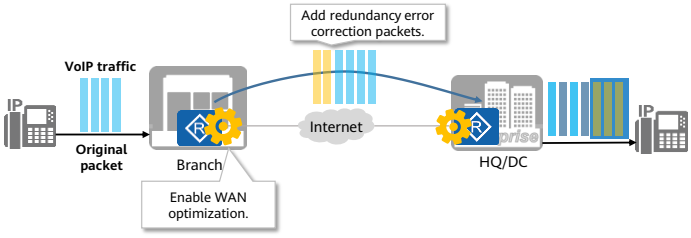


- The introduction of hybrid WANs provides multiple WAN links for enterprise service traffic. Different WAN links offer varying levels of network quality. For example, the price of MPLS private lines is high and the corresponding link SLA quality is guaranteed. Although Internet links are improved greatly and can carry applications that support high bandwidth, the delay and packet loss occur frequently on Internet links and SLA is not guaranteed, making the Internet unsuitable for delay-sensitive voice and video services. The solution to this issue is to implement link selection based on the SLA quality requirements of applications. Specifically, the quality of different WAN links is measured, and the requirements of applications regarding network quality (such as packet loss rate, delay, and jitter) are defined. Among all WAN links that meet SLA requirements of applications, enterprise users can define route selection policies to preferentially transmit high-value applications through high-quality WAN links. For example, voice traffic (high-value traffic) is preferentially transmitted over high-quality MPLS links. The network has the capability of dynamically adjusting paths. When the MPLS link quality deteriorates and does not meet application SLA requirements, the network can automatically switch voice traffic to another WAN link that satisfies application SLA requirements.

SDN Overview | SD-WAN Characteristics | Core Values of SD-WAN

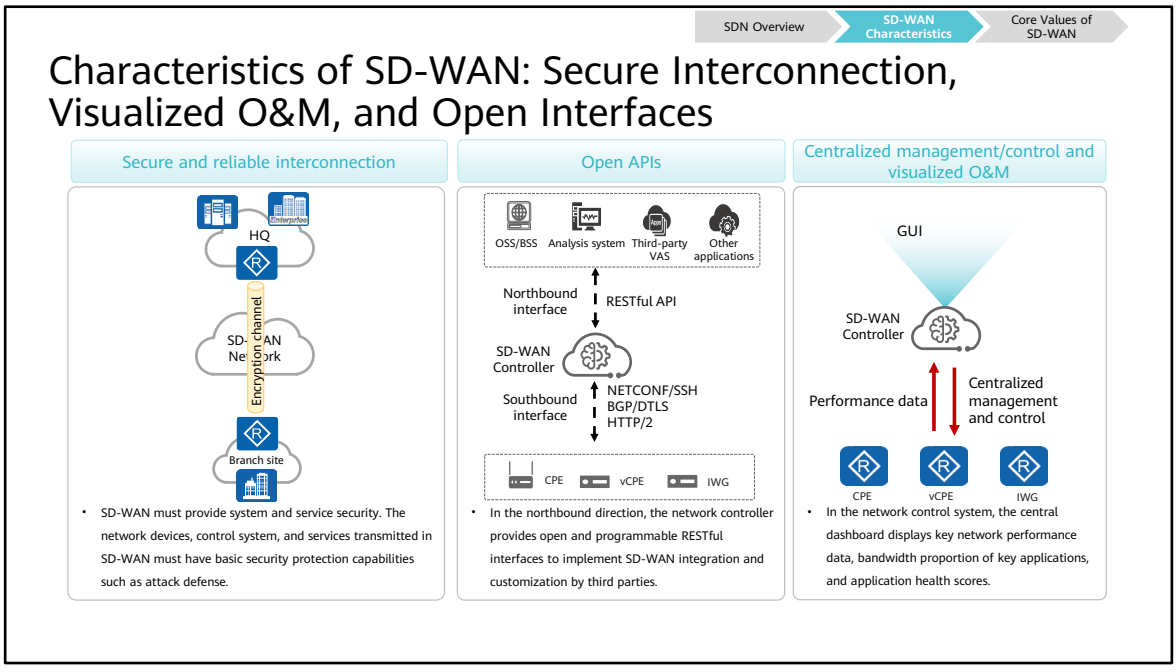
Characteristics of SD-WAN: WAN Optimization

- WAN optimization, improving WAN link quality

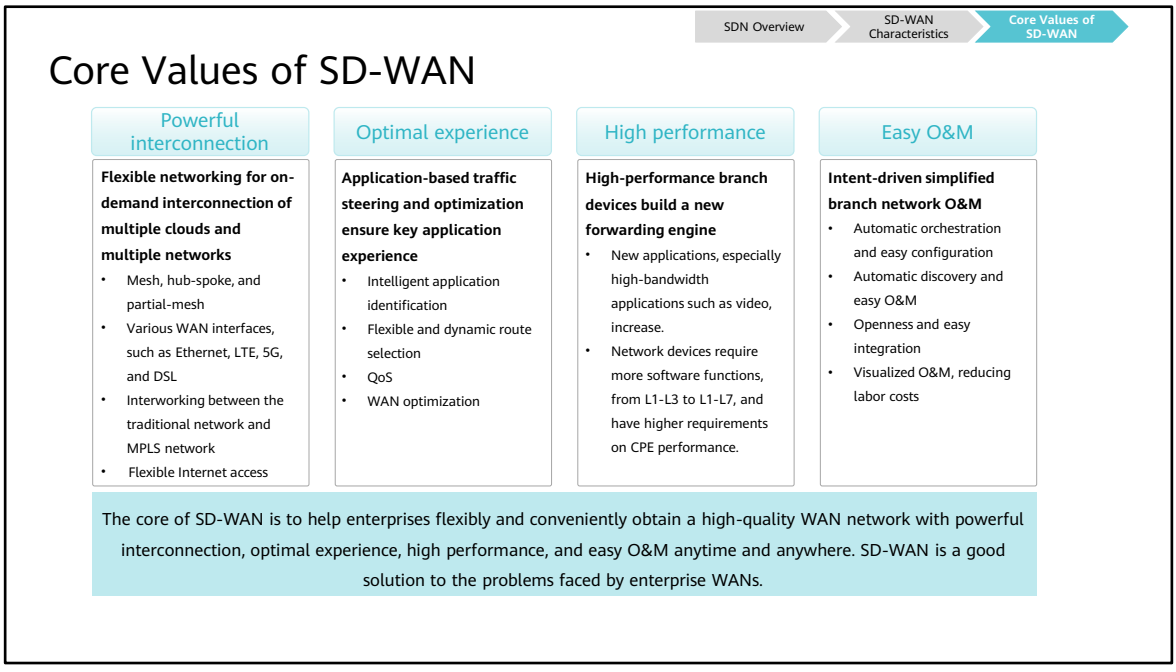


- When the quality of a WAN link deteriorates, for example, packet loss or long delay occurs, WAN optimization technologies need to be used to improve network fault tolerance and ensure data transmission quality. Common WAN optimization technologies include transmission optimization, data optimization, and packet loss concealment optimization.

- The prerequisite for application-based traffic steering is that there are WAN links that meet SLA quality requirements. When the quality of a WAN link deteriorates, for example, packet loss and long delay occur, WAN optimization technologies need to be used to improve network fault tolerance and ensure data transmission quality. Common WAN optimization technologies include transmission optimization, data optimization, and packet loss concealment optimization.
- Forward Error Correct (FEC), a common packet loss concealment technology, is used as an example to describe the value of WAN optimization. The core of FEC is to improve the fault tolerance of application data to links with deteriorated quality by reconstructing or optimizing the data transmission protocol. FEC packets are encapsulated in normal data flows to record packet digest information. During data transmission, some service packets are lost due to packet loss on the network. At the receive end, the device can restore the lost packets based on the FEC field to ensure the integrity of data transmission.
- The core of WAN optimization is to use extra compute or storage resources to improve network transmission performance and application experience. WAN optimization is an effective technical means to ensure that user service experience is not affected when the link quality deteriorates on an enterprise WAN.



- Secure and reliable interconnection
  - The transmission of enterprise WAN application data requires security assurance, including system security and service security.
    - System security includes the security of network devices and network control systems, which must be connected to the WAN and may also be connected to the Internet. Because of this, they must have basic security protection capabilities, such as attack defense.
    - For enterprise services, service data is transmitted on the WAN. Therefore, authentication and encryption are required to prevent data leakage.
- Centralized management, visualization, and easy O&M
  - Enterprises use the centralized management and O&M system. This system must be able to remotely manage branch devices, as well as display the WAN topology and remotely monitor alarms, logs, and other key event information of each branch device in real time.
  - In the centralized network control system, the central dashboard displays key network performance data, bandwidth proportion of key applications, and application health scores.
- Northbound open APIs
  - The network controller provides open and programmable northbound RESTful interfaces. Third-party BSS/OSS software interconnects with the network controller through northbound APIs.



- Powerful interconnection: flexible networking for on-demand interconnection of multiple clouds and multiple networks
  - SD-WAN flexibly uses hybrid links, such as optical fibers, DSL links, and LTE links, to quickly provision networks and reduce link costs.
  - In addition, SD-WAN provides a broad variety of networking models, including hub-spoke, full-mesh, partial-mesh, hierarchical networking, and IaaS/SaaS access, meeting requirements of different enterprise services.
- Optimal experience: Application-based traffic steering and optimization ensure key application experience
  - SD-WAN can monitor the quality of multiple links in real time, detect link connectivity, and record the packet loss rate, delay, jitter, and other real-time status information.
  - SD-WAN also provides multiple application identification methods to accurately identify application information in traffic.
- High performance: High-performance branch devices build a new forwarding engine.
  - In contrast to traditional enterprise branch devices that feature packet forwarding at Layers 1 to 3, SD-WAN branch devices deliver application-based full service processing at Layers 3 to 7. Their high-performance forwarding capabilities help enterprise branches build a new forwarding engine to allow enterprise services to operate normally.
- Easy O&M: intent-driven simplified branch network O&M
  - SD-WAN inherits the two basic design concepts of SDN: centralized control and intent-driven. This makes it possible to implement intent-based centralized management and control on the entire network. Based on centralized control, SD-WAN provides the network-wide monitoring function to obtain branch link status in real time, making the network-wide status visualized.

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Quiz

1. (Multiple-answer question) Which of the following are disadvantages of traditional WANs?
   A. Low network flexibility
   B. Complex network protocols
   C. Enterprises are highly dependent on network device vendors.
   D. Difficult O&M

- 1. ABCD

Summary

- Generally, enterprise WAN interconnection depends on WANs built by carriers or self-built WANs.
- After services are cloudified, flexible networking and fast service optimization are required.