ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 11 , November 2021

Conceptual Model of Distributed Resources of a Cloud Data Center Based on a Software-Defined Network

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ABSTRACT: In connection with the recent increase in the number of autonomous data processing centers, their virtualization and development based on cloud computing technologies, cloud data center have been formed. With the increase in the number of users on the Internet and the increase in the number of applications available in the cloud, the load on the network is increasing. To efficiently deliver the resources and services of autonomous cloud data centers located at different locations to a wide range of users, it is necessary to create a structured single cloud data center that connects them using modern network tools. The article presents a conceptual model of resource allocation for a distributed cloud data center based on a software-defined network.

KEY WORDS: Software-defined network, Network, Cloud, Data center, Model, Virtualization.

I. INTRODUCTION

In recent years, there has been a growing need to reduce the amount of money spent on supporting and improving computing power and ICT structures. Therefore, cost optimization for information technology is an urgent problem. One of the solutions to the problem is the creation of a single computing complex - a data center based on the methods of a distributed system.

Creating a distributed cloud data center (DCDC) will improve the overall efficiency of the company, reduce capital costs, reduce data latency and resource migration time on the network, and significantly improve the user experience of the center resources (and applications).

As the volume of data grows, so does the popularity of data storage systems (DSS). The transport base of DSS is the Fiber Channel protocol, which connects DSS devices to each other on the basis of a special network based on fiber-optic communication channels [1,8,9].

The rapid development of ultra-broadband telecommunications networks, the creation of software defined networks, and improvements in other cloud computing technologies have led to the creation and operation of many new data processing and storage centers.

Creation of software-defined data centers. At the heart of a distributed data center solution, which includes a set of resources, is virtualization technology, which includes software defined network (SDN) technologies that work with virtualization of server computers and storage media, network virtualization, and data transfer and management processes. These technologies ensure that the data center creates a single flexible resource and network of the required quality level, so it is necessary to create data centers based on these technologies.

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II. FORMULATION OF A PROBLEM

The efficiency of a distributed cloud data center depends on many factors, especially the quality of the network layer. Therefore, the structure at this level should be designed to take into account the maximum load of different types of data flows. This is because a virtual computing resource created to perform a user request can consist of virtual resources generated on the physical computers of autonomous data centers connected to different switches. In this case, the network layer must ensure the online exchange of data between scattered virtual machines, which can lead to a sharp increase in the load on the network media.

The interconnection of cloud data centers is based on telecommunications networks and communication channels. The integration of the centers located at different points will not be achieved if the Internet is based on the existing telecommunications facilities. Because its communication channels are loaded with other types of data streams, the bandwidth is slightly lower than the speed of data processing systems. Therefore, to create a distributed cloud data center, it is advisable to create a separate high-speed data network based on a software defined network, as the network is managed centrally using a single OpenFlow protocol. Designing cloud-to-network interconnections in a “one-to-one” manner requires large capital expenditures, while interconnection through a hub or on a single-link network leads to increased latency. Designing the structure of a distributed cloud hub network in the form of a K-linked topological scheme is the optimal solution [4].

The process of data transmission in the telecommunication network of the DCDC is carried out in accordance with all the procedures provided for in the SDN. The autonomous data center searches the rules for the transfer of packets from the local network to the switch in the flow chart and follows them. If the required rules are not available in the flow chart, the packet is transmitted via the OpenFlow protocol to the SDN controller (network manager) through a protected channel, which develops the necessary rules for packet transmission and installs them in the flow tables of the respective OpenFlow switches. Data packets are transmitted from the source to the address according to the rules established in the flow charts.

The infrastructure of the SDN network is interconnected in a certain order by means of high-speed communication channels and has a distributed topological structure.

III. THE SOLUTION OF THE PROBLEM

The provision of DCDC resources and services includes the following components: cloud user, DCDC central management system, DCDC resource infrastructure, communication network tools.

Execution of the request received by the software defined DCDC is provided on the basis of the presence of these components. In this case, each component performs a specific function.

A cloud user can be a person or an organization that requires access to a particular resource of the DCDC, so the cloud user performs the functions of "requesting" and "consuming" resources from the data center. These functions are usually performed using network tools and protocols.

The Central Management System (CMS) of the DCDC performs the functions of identifying and authenticating user and cloud resources, as well as managing the processes of allocation and provision of DCDC resources [5,11].

The infrastructure of the DCDC resources and services shapes the resources and services and ensures their readiness to provide them, that is, it provides users with "access" to resources and services. Within this infrastructure, there are cloud service models that provide several different services: Software as a Service (SaaS), Platform as a service (PaaS), Infrastructure as aService (IaaS).

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DCDC Resource infrastructure solves various problems based on service models:
SaaS - installs, manages, provides and maintains software within the cloud infrastructure;
PaaS - manages the cloud infrastructure and software that creates the middleware between the cloud user and the cloud resources;
IaaS – provides and manages the computing and data storage facilities, network and hosting environment, and cloud infrastructure that consumers need.

Communication network tools provide DCDC consumers with access to cloud services and resources through telecommunications networks and other access devices, as well as ensure the interaction of DCDC components in the execution of cloud user requests. Computers, laptops, mobile phones, mobile devices with an Internet connection, and more can be used as network connectivity devices. It is advisable to use a software defined network as a communication network tool, as it allows for a wide range of virtualization methods [2,3].

DCDC's data storage infrastructure supports different levels of data storage and presentation services to users and forms a new architecture of geographically dislocated data storage systems.

DCDC storage tools perform the functions of delivering information resources on demand in a large-scale and multi-user environment. These functions are implemented using the appropriate protocol and external and internal interfaces. Access to data storage media using external interface tools and middleware programs. The internal interface ensures the physical storage of information in the disk environment within the DCDC [10].

Thus, in general, it can be concluded that the cloud environment of the DCDC consists of three conceptual environment levels:

- level of physical resources - Includes all physical resources of the DCDC: computer equipment (computing resources, memory), network equipment (SDN controllers and applications, switches, firewall, high-speed communication channels and interfaces), information storage components (hard drives) and other physical elements of the DCDC infrastructure.

- Level of allocation and provision of resources and services of DCDC - Determines the main resources and services provided by the central government of DCDC.

- DCDC creates virtual resources within the infrastructure, that is, it provides software components (hypervisor software, virtual data storage, etc.) used to implement the cloud infrastructure. Install cloud resources and service applications for these applications. The layer ensures that the physical environment is ready to work in the cloud.
The following is a conceptual model for the provision of distributed cloud data center resources based on software defined network technology (Figure 1).

Cloud controls DCDC act as a single management system. It is the " main access" to the center's resources, creating a queue for each requested program. In addition, the cloud controller manages the creation of a certain number of virtual machines on the physical server computers of the DCDC. The initial capacity and number of virtual machines created will be determined in accordance with the requirements specified in the Service Quality Assurance Agreement (SLA) or empirically [6,7].

The number and capacity of virtual machines based on physical server computers in the DCDC may vary depending on the load. regardless of the physical segments (autonomous cloud data centers (ACDC) within the DCDC). The user's request is first sent to the DCDC control center, that is, to the cloud controller. The "load distributor" block in the cloud controller finds the required resource according to the request and directs it to the queue organized at its entrance.

The model describing the main features of the topological structure of DCDC consists of several components:

$$DCDC = \{CR, CC, ST, SS\} \tag{1}$$

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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$CR= \{ CR_1, CR_2 ,..., CR_M\}$ – a set of computing resources of autonomous cloud data centers connected to the appropriate switches of the software configurable network, M – The number of cloud computing centers within the DCDC; CR_i – i is the computing power of the cloud center.

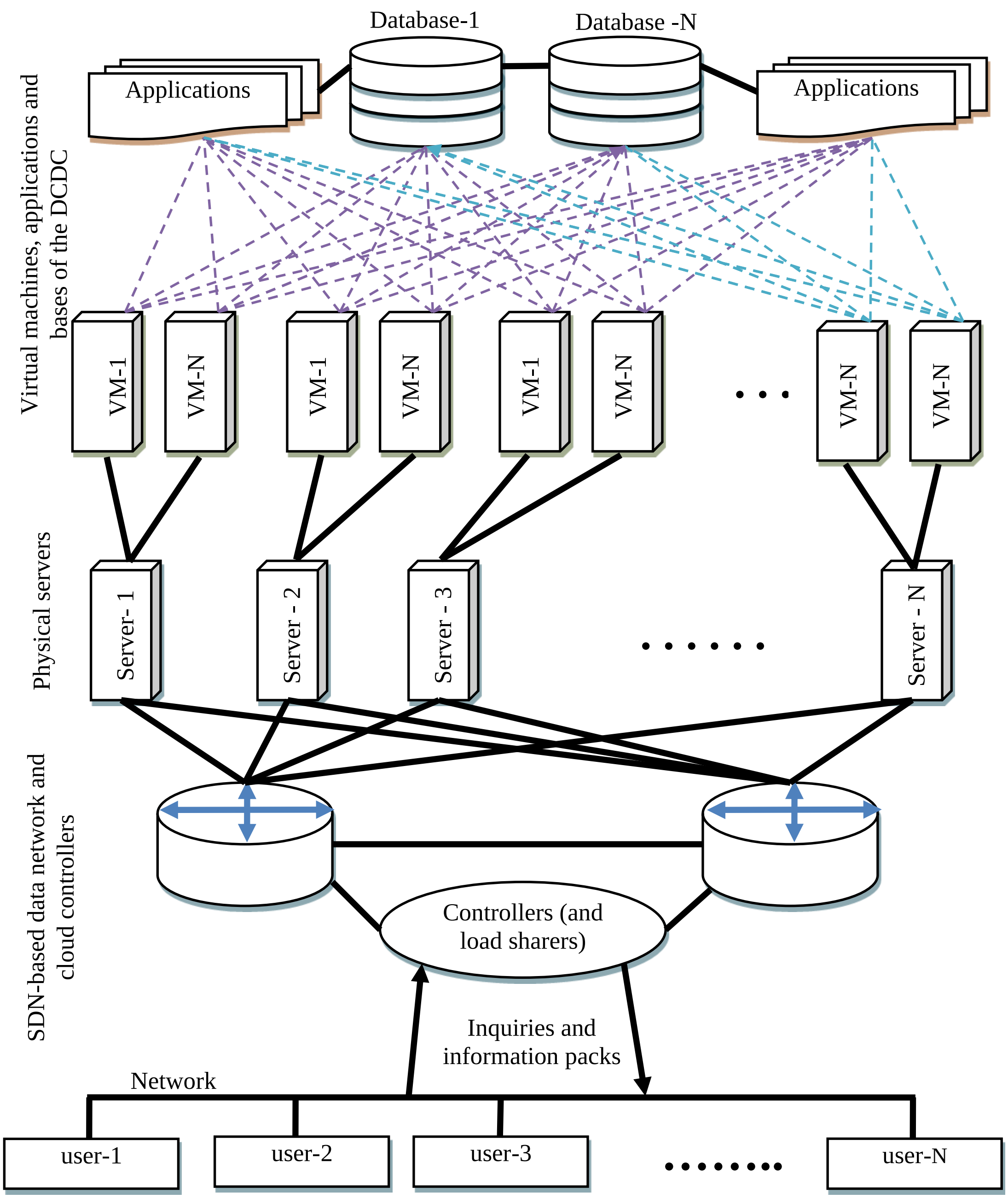

Figure 1.SDN-based logical scheme of DCDC

Each virtual machine embedded in autonomous cloud data centers physical computers is defined by the following set of metrics: virtual machine (VM) computing power, memory capacity applications, etc., The physical computer settings on which the VM is stored, which autonomous cloud data center it belongs to, and so on. If the VM is migrated, that is, transferred to another physical center in the DCDC, the parameters will be changed depending on the new location.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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Compute resources in stand-alone cloud data centers connected to the SDN *i* switch are expressed in terms of static and dynamic parameters. Static parameters include the number of computing resources concentrated in segments H_i, their capacity d_j, RAM and disk memory volumes q_j, y_j. Dynamic parameters include: The employment and non-employment of the computing resources in segment j connected to the SDN i switch at a given time t $R_j(t)=[r_1(t), r_2(t),..., r_j(t)]$; load level $U_i(t)=[u_1(t), u_2(t),..., u_i(t)]$; complex of tasks solved in the segment of computing resources v_j; the number of computing resources not provided by the *j*-segment; memory capacity, other indicators used during the operation of computers.

At the same time, it is characterized by the following parameters: virtual machines of different capacities, created on physical DCDC computers, on which physical data parameters of the cloud data center are created on the physical computer; Their computing power and number; types of virtual applications installed on each VM; the amount of RAM and disk memory; How virtual machines are related, etc.

This data is regularly collected using special software at intervals determined by cloud controllers.

CC - cloud controllers, central DCDC management system - regularly receives information about user requests, DCDC resources, the state of network parameters at regular intervals and makes appropriate decisions;

ST = { ST_1, ST_2, ST_3, ST_4, ST_5 } - A set of networking tools (ST) used in a DCDC network topology: ST_1 – Number of SDN infrastructure Switches; ST_2 – Number of SDN control level controllers; ST_3 - High-bandwidth physical links between SDN infrastructure layer switches; ST_4 – The number of secure communication channels between SDN controllers and switches; ST_5 – A set of networking tools that allow you to connect the DCDC storage system to physical and virtual machines.

SDN distributed cloud data center infrastructure switches based on the OpenFlow protocol have both static parameters and dynamic characteristics. The static parameters include the supported versions of the OpenFlow and Ethernet protocols, the maximum bandwidth of DCDC network tools for each network connection, the bandwidth values of communication channels between SDN switches in the absence of network load, the maximum data flow can be processed and other information. The dynamic characteristics of switches include information about the status of flow charts at a given time. These include general information about the state of the switching ports (enabled or disabled), the total number of received and transmitted packets, the loading time of received and transmitted packets (for example, the load level of the communication channel between switches at time t), total receive data sent and received, packages sent and received in error, etc.

SS - { SS_1 , SS_2 ,…, SS_M} – storage systems are connected to physical and virtual machines in DCDC segments.

The DCDC storage system consists of applications and information databases. Each storage system (SS) is characterized by the following parameters.

$$SS_i=\{V_i,w_i(t),z_i(t),y_i(t)\} \quad (2)$$

where V_i-*i* is the total storage capacity of the data center;
$w_i(t)$ - *i* is the volume of the unused part of the data store at time *t;*
$z_i(t),y_i(t)$ - *i* is the constant average read and write speed of the data store in the data store at time *t*.

This information is collected over a period of time using the OpenFlow protocol. They help determine the level of utilization of communication links and switches in the network.

IV. EXPERIMENTAL RESULTS

The process of transmitting and processing packets in a SDN network consists of the following stages:

1. The custom packet enters the input block of the SDN infrastructure layer switch. The switch has a switching table that lists the packet header and the output port number. The switch looks for the address entry specified in the incoming packet from the switch table (ie, the address of the switch to which the server computer connected to the DCDC control

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

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center is connected). If the table contains such a header, the packet is sent to the corresponding output port on the switch. Otherwise, the packet is routed through the secure channel to the SDN controller to which the switch is connected, which determines the path to the packet address based on the application routing program, creates an entry for the switching schedules of the routers, and passes it on to them. The packet is transmitted to the address of the SDN infrastructure layer through the corresponding switches and communication channels, that is, to the switch connected to the server computer on which the DCDC control center is located.

2. As soon as the cloud controller receives all the request packets, it analyzes them and determines what service the user of this network needs, finds the optimal computing resource in DCDC to fulfill it, and directs the request to its access.

3. The request is received by the DCDC computing resource (the computing resource can be a virtual machine based on a physical computer in an autonomous cloud data center) and processing begins. During processing, information can be exchanged between DCDC storage systems and other virtual machines. The processing result is transmitted to the network user.

The results obtained as a result of experiments based on the traditional and the proposed conceptual model (Figure 2) can be interpreted as follows: with a relatively low load on the network ($r \approx 0.3$), the value of the objective function in both variants is practically the same (6,623 and 7,275), but the results differed sharply with increasing load, i.e. 13,375 and 18,856 at $r \approx 0.6$, the total delay time 30,912 in the proposed version at $r \approx 0.9$ and 39,246 in the second method.

Thus, connecting autonomous cloud data centers in DCDC to a high-speed, separate data network based on a software-defined network results in a relatively short time for packet transmission

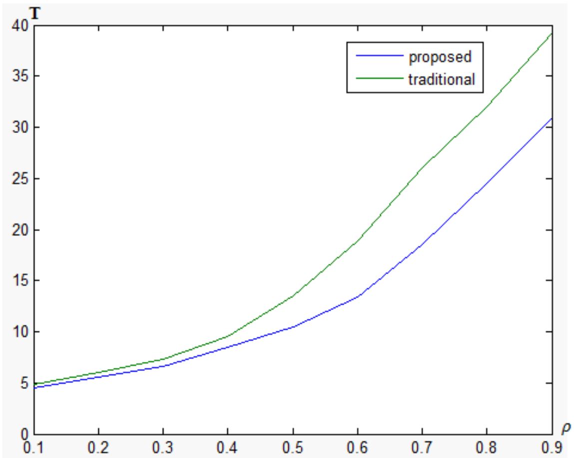

Figure 2. Diagram showing a comparative analysis of the results obtained using the two methods

V. CONCLUSION

The described conceptual model adequately describes the infrastructure of a distributed cloud data center with various topologies. Since the model is focused on supporting the OpenFlow protocol, it allows you to model various types of OpenFlow controllers and switches.

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