On Premises, Virtual, Cloud Solutions and a New Network Design Paradigm

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***Abstract*—Traditional computer network design decisions are changing. There are several reasons: the technologies that are used in networks have changed, the general concept for designing network is considered for a network infrastructure, the general approach to describing the network has changed from component to object and service, new solutions have appeared for transferring services to virtual and cloud spaces. As a result, the changed network design paradigm is reduced to five areas: designing a local network, taking into account the construction of a personal space (PNS) and the formation of a user template, network design for ground-based (unchanged), network design taking into account virtualization , designing a large network taking into account cloud services (network with a rigid configuration, a network with cloud service development).**

I. Introduction

Traditional network design solutions are changing. During the existence of IT technologies, a certain paradigm of the computer network design theory has developed. Most books stick to the basic rules. Basic concepts and methods are described in [1 – 5, 7 – 9]. They are based on the OSI model, the division into hardware, middle and software, and the component representation of the network.

These rules seem well formulated and immutable. But over the past 10 years, there have been many changes in the IT industry. These changes affected the main issues of building computer networks.

The network technologies that are used have changed. The basis of a computer network is LAN. Previously, there were many different technologies for building a LAN, but the market has chosen only one main technology, Ethernet. This happened not because this technology is the best, but because it is the cheapest, simplest and most popular. This led to a simplification of the task of building and designing a local network.

Another change is the widespread adoption of managed Ethernet switches on Layer 2 and Layer 3 . This simplified the solution of the design problems for a computer network backbone.

Similar changes have taken place in the WAN sector. The number of technologies that was used has decreased.

All this was reflected in the fundamental issues of designing computer networks.

The next factor that changed the approach to network design was the widespread implementation of virtual systems and cloud services [10, 11].

There have also been changes in the use of the network. Networks have been transferred from the hardware category to the service category [12, 13, 14].

In addition, during the COVID lockdown, the widespread use of remote access to cloud resources has also shifted the focus of network design. The issues of quality of access to resources by the user have become relevant.

The changes that have taken place make us pay attention to the general philosophical concepts for the development of the theory of network design. Such questions turn out to be common for different types of networks, not only computer ones. This is well shown in [6].

This paper considers the factors of change in the basic principles of designing computer networks, i.e. paradigm of its design.

II. Formulation of the problem

The previous analysis showed that there are several reasons for changing the computer network design paradigm:

- The technologies that are used in networks have changed.
- The general concept has changed from designing of the hardware network to a network infrastructure, in which services are considered an integral part of the network.
- The general approach is not component based, but object and service based.
- Many networking solutions are being transferred to virtual and cloud spaces.

Thus, it is necessary to form the foundations of a new computer network design paradigm.

To formalize the provisions on the formation of the paradigm, we will find out which elements of the existing procedure for designing a computer network have changed and identify the reasons for these changes. First, we will analyze the requirements for the implementation of a computer network in order to decompose the whole problem.

III. Description of the environment and conditions for network implementation

A. Architectural components of the designed network

First of all, a computer network is designed to improve the business processes of the main organizational entity (firm, company). In fact, the organizational object is considered as an object of automation of information processes. In this regard, computer networks are always associated with the topological

space in which they are deployed. It's about rooms and buildings. Such a classification in a simplified form can be represented as a computer network location spaces: a house, a small office, a large office, a group of buildings, offices in a city, offices in different cities.

B= {b1, b2, b3, b4, b5, b6} = {<house>, <small office>, <large office>, <group of buildings>, <offices in a city>, <offices in different cities>}.

Networks located in these spaces can be divided according to the principle of scaling: home networks, small offices, office networks, campuses, corporate networks.

C = {c1, c2, c3, c4, c5} = { < home networks>, <small offices>, <office networks>, <campuses>, <corporate networks>}.

Each of these networks consists of architectural macro components of computer networks. These include: local LANs, ONB backbones, global WANs.

N = {n1, n2, n3} = { < LAN>, <ONB>, <WAN>}.

The real solution is the result of choosing one-to-one correspondences between these three sets (B, C, N), let's call them the architectural components of the designed network.

Therefore, if some technologies change, then these changes will be reflected in each of the sets and the relationships between them.

This is the first conceptual conclusion for the network design procedures.

B. The traditional design procedure

The traditional design procedure is reduced to the implementation of the main five steps (shown in Table I). These are all typical steps in the general network design paradigm.

TABLE I. DESIGN STEPS

Step	Action	Period (traditional)	Period (cloud services)
First,	creation of engineering structures to accommodate equipment and ensure its operation.	Months	**NO**
Second,	choice of technologies	Weeks	Day/Script
Third,	equipment selection	Weeks	Day/Script
Fourth,	Additional engineering work on equipment installation	Months	**No/Logical**
Fifth,	Equipment placement and setup	Weeks	**Hours**

Each step requires a certain period to complete (see Table I) - Period (traditional). As can be seen from the table, the most labor-intensive and time-consuming steps are engineering works. In the case of using new cloud technologies, these steps are significantly reduced, as shown in Table I - Period (cloud services).

IV. CHANGING TECHNOLOGIES AND CONCEPTS

A. Changing technologies of computer networks

How have the network technologies that are used changed?

LAN - there were Token Ring, ArcNet, FDDI, Ethernet, It is remained only Ethernet и WLAN+Wi-Fi

ONB – there were Ethernet 1G, it is became Ethernet 10G, 40Gg. and WLAN

WAN – there were X.25, FrameRelay, ATM, xDSL, ISDN , It is remained only Ethernet

As you can see, Ethernet remains the only technology for all networks.

What components does Ethernet use?

These include: cable and basic network equipment. It uses twisted pair 5e and single-mode optical fiber cables. Also it uses typical switches 2, 3 layer as an equipment.

The number and variety of components has significantly decreased. Thus, the overall design procedure has become easier.

However, Ethernet has expanded to include a large number of new technologies [1].

B. Using object-oriented and service-oriented design.

The traditional approach focuses on network components that are placed in real space. The placement is determined by the convenience of solving engineering problems (power supply, cooling, availability of channels). The traditional approach assumed that the network is placed first, and then services are placed on this network.

In the new approach, we consider services, their quality and availability to be the main ones. Depending on this, the equipment is placed and the entire network is configured.

The next change is when all components and common functions in the network are considered as objects and services. This does not change the design paradigm, but improves management capabilities (network monitoring, administration, management).

All this leads to the typing of solutions for a network design.

C. Using Virtualization Techniques.

The following changes are related to the use of virtualization methods. In this case, powerful hardware servers or network clusters are used, and software servers are deployed on them. The advantage is that each service is deployed on its own logical computer (virtual server). This achieves flexibility in the formation of the service infrastructure of the network and its high reliability. All services can be easily and quickly reconfigured. If the service fails, just reboot the virtual machine. In this case, the network design is reduced to deploying the terrestrial network (the old solution) and building a new logical configuration of virtual resources on it. This is an intermediate solution before moving to the cloud.

D. Use of cloud technologies

The most significant change in design procedures is the use of cloud technologies. The main thing in cloud technologies are special services. In fact, these are virtual components that are not located on the hardware servers of the network, but in some cloud space.

A service can be remote user computers, servers, switches, routers, networks.

At first there were only three main services IaaS, PaaS, SaaS. Currently, there are many services. All of them have a generic name XaaS [10], [11] .

You have to pay to use cloud services. If at first only large companies used the transition to the cloud, now more and more these services are used by small companies and then every user. As the cost of cloud services decreases, they are becoming more affordable. Most importantly, there is no need to spend money on engineering support for the network itself, on renting premises, or on setting up equipment. There are no problems with the reliability of the network.

One procedural solution for cloud technologies is a set of methods for migrating an existing network to the cloud. This methodology occupies a separate place in the overall new paradigm of computer network design.

E. Using a client-centric approach

This is another new change in general design concepts. This approach became real only after the transition of the network to the cloud.

For the traditional approach, it was believed that in order to access network resources, the user must physically come to his workplace. The workplace was located next to the computer network. Thus, the main thing was the network, and the user chose his workplace in it. All this was housed in the office (physical buildings). The larger the company, the more office buildings are needed and the more terrestrial network is needed.

The new approach assumes that the user's place can be anywhere the user wants.

The main thing is personal communication channels for the user, their quality and performance. And now the official placement of the user is not important. The fact that it performs functions and accessibility to services is important. In this case, the virtual infrastructure of the network is designed so that it is convenient to access resources for any user (client). In addition, the task of creating good conditions for access to cloud resources becomes the task of the companies in which this user works.

All these changes were reflected in all the main architectural components of the designed network (B, C, N).

What did it lead to? How has the paradigm changed?

Consider each version of the automation object.

V. Results of a design paradigm change

1) Home network: The home network is dominated by the user's personal network space - PNS. It doesn't matter how it's built. It is important that there is a channel (usually Wi-Fi). And this space is filled with information services by the user. In this case, the user forms for himself several profiles that characterize him as a person in some information subspace. The whole network design paradigm assumes the formation of a virtual infrastructure of service components so that the user can easily access them. In addition, within the framework of the paradigm, a certain template of a user workplace with specified characteristics is formed. The standard client-server approach is transferred to the user and cloud services.

2) Small office: For small offices, simple cloud services are used to provide access to the main service spaces.

3) Large company: A new virtual network infrastructure is being formed for large companies. Here are the biggest changes. For terrestrial networks, infrastructure and topology are something that never changes. For cloud systems, the infrastructure can change very often depending on the services and their characteristics. In this case, the infrastructure is created for services. Automation tools allow this infrastructure to change quickly and flexibly.

VI. A new paradigm for designing computer networks

Based on the analysis, we have five main areas:

- Designing a local network, forming requirements for a personal user space (PNS) and forming a user template (new).
- Designing on premises network (unchanged).
- Designing a network with virtual resources (new).
- Designing a large network with cloud services (network with a rigid configuration, a network with dynamic cloud services) (new).

Additional rules:

- A computer network is designed taking into account the transfer of its resources to the cloud space.
- A computer network is designed with a focus on supported services.
- The logical scheme of the infrastructure of services becomes the basis for a computer network.
- The network infrastructure is designed taking into account user's network access patterns.

Each of the directions is filled with its own technologies and methods for deploying the network and changing it.

VII. Conclusions

The paper considers the formation of a computer network design paradigm for the development of new information technologies.

An analysis of the existing conditions for the introduction of computer networks, an analysis of changes in technologies and concepts of network design has been carried out. The

paper shows how the paradigm of designing computer networks changes in the new conditions.

As a result of the analysis, a new paradigm of designing computer networks has been formed.

The proposed results can be used in the formation of academic curricula for the training of IT specialists in wide areas.

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