Bulgarian Defense Institute
"Professor Tsvetan Lazarov"

ABSTRACT

of dissertation work

for the award of the educational and scientific degree "Doctor"

Professional field:	*5.2. Electrical engineering, electronics and automation*
Doctoral program:	*Automated systems for information processing and management*

on the topic:

MODELS OF CLOUD ARCHITECTURES FOR BUILDING A COMMUNICATION AND INFORMATION ENVIRONMENT FOR COLLABORATION WORK AND MANAGEMENT

Kristina Lyudmilova Ignatova

Sofia

2022

The dissertation is structured into an introduction, three chapters, conclusion, list of publications related to the dissertation, used bibliographical references, lists of figures and tables, list of accepted abbreviations, glossary of terms used.

The designations of the chapters, formulas, figures and tables in the abstract coincide with those in the dissertation.

The dissertation, in its main part, contains 160 pages, 35 figures, 5 tables and 131 used literature references.

The defense of the dissertation will be held on ……… .... ……… .. from ……………. Hours in the hall ………………………… of the Institute of Defense "Professor Tsvetan Lazarov ", at an open meeting of the scientific jury composed of:

1. ……………......................……..………..
2. ……………..……………..
3. ……………..……………..
4. …………..……………..
5. …………..……………...

Spare members:

1. …………..……………..
2. …………..………………..

<u>Scientific adviser:</u> Prof. Dr. Eng. Rosen Iliev

<u>Author:</u> eng. Kristina Lyudmilova Ignatova

<u>Title:</u> Models of cloud architectures for building a communication and information environment for collaborative work and management.

INTRODUCTION

Information technology (IT) is increasingly used in the daily lives of modern man. Closely related to them are the recently emerging cloud technologies providing cloud IT services. These technologies ensure the redundancy of information services and resources, becoming reliable means of providing "critical" applications such as those in the field of security and defense.

The subject of the dissertation is to analyze modern cloud architectures and to propose appropriate models for building a communication and information environment for collaboration work to provide officials of defense structures with the necessary IT services and resources.

The first chapter reviews and analyzes cloud technologies, cloud platforms, collaboration and collaboration environments. The possibilities for building an environment for collaboration work are considered, as well as an approach for building such an environment using generalized net (OM) is proposed.

At the end of the first chapter conclusions are made and the purpose and main tasks of the dissertation are formulated.

The second chapter presents original generalized net models of cloud architecture for building a communication and information environment for work, which are: generalized net model for building a communication and information environment for collaboration, model of video communication in the cloud for collaboration, cloud model infrastructure for building an environment for collaboration. A method for determining the estimation parameters of the nuclei in the OM models is also proposed.

The third chapter examines the possibilities for operation of the models through the software environment for simulation of generalized net GN-IDE (Generalized Nets Integrated Development Environment), and presents an approach to creating a cloud environment for collaboration, as well as a model (option) for building a prototype of communication and information environment for collaboration work of defense officials.

The conclusion describes the contributions of the dissertation, as well as guidelines for future work.

The following **restrictions** have been adopted for the implementation of the main tasks in the dissertation: When choosing an environment for collaboration work, emphasis is placed on one that will support the activities of defense officials; The summary network models discussed in Chapter Two are not sufficiently formalized, but have a more general verbal description, as the aim is to show more clearly how they can be used to create a functional cloud environment for security and defense officials.

FIRST CHAPTER

ANALYSIS OF CLOUD TECHNOLOGIES, ARCHITECTURES AND COOPERATION ENVIRONMENTS

1.1. Analysis of cloud technologies and architectures

1.1.1. Nature of the cloud and cloud technologies

The dissertation examines a number of sources that define the concepts of information cloud, cloud computing, advantages of cloud computing, cloud architecture, virtualization.

As a possible definition of the term "information cloud" is considered in [40, 54, 66, 85], as a source [66] argues that "scalability and optimization of resource use are key elements for the cloud."

The dissertation under the cloud will mean an environment for easily replaceable virtualized resources (hardware, various components or services) that can be reconfigured to meet the needs of the organization that uses it.

The term "cloud computing" was introduced by Eric Schmidt of Google on August 9, 2006 at a conference on search engines, which explained a possible approach to computing software as a service (SaaS) [12].

For the purposes of the dissertation, the definition by which we will understand cloud computing is that they allow users to have access to data, services and other resources through network connectivity (internet connection).

1.1.2. Virtualization

Another important term considered in the dissertation is virtualization. Its definition is given, which defines virtualization as a type of environment in which computer services are independent of the physical infrastructure. The types of virtual machines and the requirements for working with them are also given.

1.1.3. Characteristics of cloud architectures

The characteristics of cloud architectures are considered, which are: huge resource reserve, virtualization, elasticity, automation, consumption measurement.

The components that make up a cloud architecture are interconnected and are illustrated in FIG. 1.4.

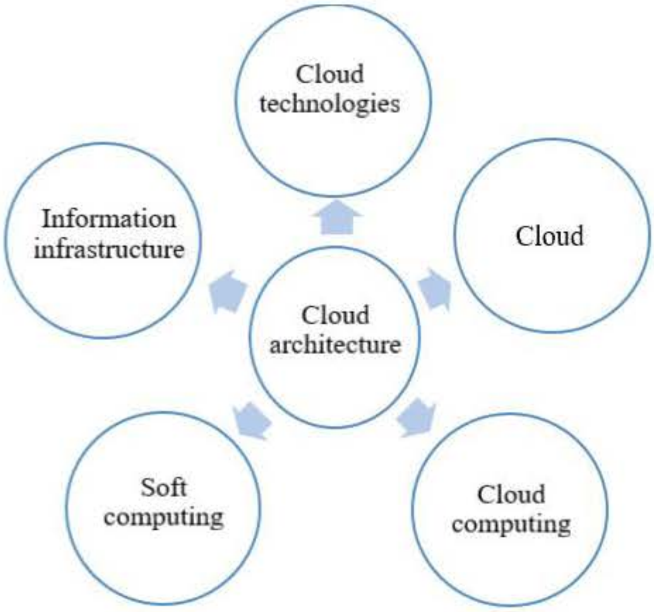

Fig. 1.4. Components of cloud architecture

1.1.4. Types of clouds

The types of clouds according to their visibility, which are relevant to the present work, are considered, and also the differences between the public and private cloud are given.

1.1.5. Types of cloud technologies

Depending on the service they offer, the main types of cloud technologies are: IaaS (infrastructure as a service), PaaS (platform as a service), SaaS (Software as a service). They are described in more detail way in the dissertation. In addition, there are other cloud technologies such as: HaaS (Hardware as a Service), SecaaS (Security as a Service), TaaS (Testing as a Service), BpaaS (Business Process as a Service), WaaS (Workplace as a Service), FaaS (Framework as a Service), DaaS (Desktop as a service) and others.

1.1.6. Analysis of cloud technologies

Of the cloud platforms listed above, SaaS (software as a service) offers the easiest access to various services and resources, and this service has the highest usability rate to date. Other technologies that would be useful for building a virtual platform for easy access are PaaS - "platform as a service" and IaaS - "infrastructure as a service".

IaaS technology (infrastructure as a service) requires more time to integrate. In it, users themselves define and implement certain parameters, such as: RAM, time consumption, operating system and others. This requires more time for research, planning, implementation, and the need to understand the subject.

Other cloud services that would be useful for building virtual platforms for easy access to services and resources are: TaaS (testing as a service) and MaaS (monitoring as a service) and. Both services are important because the first one offering testing of the current infrastructure with a possibly of integrated new one, while the other offering real-time security tracking against malicious attacks and actions.

1.1.7. Research and development of cloud architectures

The development of cloud architectures is discussed in [78], and in [20, 71] the reference cloud architecture and its application are described.

1.1.8. Challenges and benefits of cloud architectures

The challenges of cloud technologies focus on providing security, consistency and abstraction of services, scalability, flexibility, interoperability and portability, balance and more. IaaS, PaaS and SaaS are platforms that are basic implementation models.

The challenges in the implementation of services in cloud computing are presented through the so-called "Seven Level Model". According to [42], the Seven-Step Model of Migration into the Cloud is: conducting estimates of migration in the cloud; isolation of dependencies; depiction of the architecture and structure of a map; re-design of architecture and structure; achieved functionalities and required characteristics; testing; iteration and optimization.

1.1.9. Security of cloud technologies and architectures. Risk Assessment

Information-based systems are subject to malicious attacks on a daily basis. The risks associated with them and which need to be addressed are: management, investment, budget, legal responsibility, safety and others. Attention is paid to the risk assessment, as well as the risks associated with cloud technologies.

1.2. Environments to support joint activities

1.2.1. Group software and collaboration environments

An analysis of the group software and how it could be used in relation to the present work has been made. Sources [51, 102] give the definition of group software and real-time group software systems.

1.2.2. Collaborative and Cloud Environments

As a possible environment for collaboration is given the product Microsoft Sharepoint, which can work in the so-called intranet environment, an environment that works without an available internet connection. Therefore, one of the tasks in this work is to find a set of software applications that can be installed on private clouds, without an Internet connection, where to provide the necessary IT services to users, especially in the field of defense.

1.2.3. Software products for collaboration

Cloud platforms for collaborative environments that can be used for defense purposes are discussed. These environments are: Asana, Yammer, Nifty, Team Viewer, FreshConnect, GoToMeeting, EasyProjects, MiCloud Connect, Microsoft Teams, Cisco Webex, Skype for Business, Proxmox VE, OpenStack, Microsoft Office 365. Skype for Business is an environment that could be used for collaboration for the needs of defense, as it can work in an intranet environment.

1.3. Cloud technologies and their place in defense

1.3.1. Application of cloud technologies for the needs of defense

One of the applications of cloud technologies in defense is the ability to build a communication and information environment for collaboration work and management, as well as to build highly reliable virtualized platforms for access to data, information and services to support the management process.

According to [15], four steps are identified that allow the gradual implementation of the corporate cloud environment for defense: step 1. Promoting the introduction of cloud computing by creating a strong governance structure, step 2. Optimizing the consolidation of data centers through implementation of a limited set of standardized software platforms and data centers, step 3. Establish a corporate cloud defense infrastructure as a basis for its rapid integration, step 4. Deliver cloud services using commercial service providers and continue to develop and implement cloud defense services.

1.3.2. Development of information technologies in defense

The development on a modern IT base of data centers in our country began in 1999 and after 2016 and in the last few years a prototype of a cloud data center for the needs of defense has been built.

Recently in the field of defense and in particular in the Institute of Defense there is the so-called hybrid model of a data storage subsystem. The main thing in this method is to build a virtualized storage system using a virtual machine.

1.3.3. Challenges to the security of cloud technologies

Security is a major challenge in the implementation of cloud technologies. Security measures need to be put in place to reduce risks. To date, several areas have been identified that require more attention to the security of cloud technologies. Some of these areas are: security, freedom of information, internet records and others. An important area to pay attention to is the protection of personal data, especially when it comes to the field of defense. In order to minimize as much as possible the occurrence of data security breaches in the cloud environment, it is necessary to encrypt this data.

1.3.4. Cloud infrastructure to build a collaborative environment

There are several definitions for describing the term 'cloud infrastructure', one of which is to consider it as a physical structure, as noted in [11]. Thus, the term cloud infrastructure refers to the physical architecture, computing systems that perform and display cloud server activity. It is a collection of different hardware and software components that perform specific actions depending on the requirements of the cloud computing model.

1.3.5. Information infrastructure for building an environment for collaboration work for the needs of defense

Information infrastructure (AI) is a set of communication network, computer systems, database that support the work process of defense personnel. This infrastructure includes means for collecting, distributing, storing information, applications, standards, protocols and other resources.

Building a cloud-based data center system in the Ministry of Defense would consolidate hardware information resources and allow flexibility and scalability in their use. Cloud computing would improve the availability of services by making them more reliable and faster.

The Institute of Defense designs one of the first information circles for collaboration work in our country. It is based on the use of high-availability (High availability) server architecture, which includes 2 active high-speed servers and a common disk space (array), as the information environment is demonstrated and used successfully in joint training of MoD and BA structures, several ministries and departments. , 9 district security councils and their subordinate municipalities.

1.4. Mathematical toolkit for describing cloud models for collaboration

1.4.1. Modeling with the help of generalized networks

1.4.1.1. Definition of a generalized network

Generalized nets are considered as a tool that can be used to build an environment for collaboration based on cloud architectures.

Generalized nets (GNs) are an extension of Petri nets. GNs are a tool for modeling and optimizing parallel and competitive processes in complex systems and for solving problems for which other tools prove inapplicable or ineffective [16].

The main building block of OM is called a transition as it is a set of positions marked with a "circle" and the symbol "triangle with a dash". The position from which the arc emerges (always no more than one) is called the entry position, and the position from which the arc enters is called the exit point for the transition. At every 2 positions, input and output, a predicate is compared, which is an element of the matrix [36]. This matrix is called the transition condition, and the vertical line with a triangle is a symbol of this condition. Each transition has at least one input and one output position.

At the positions of the transitions are particles that can be called kernel. The kernel move in the OM, passing from one position to another through the transitions.

The transition is from one position to another if the predicate in the indexed matrix has a value of true. Otherwise (false), the kernel does not move to the starting position.

Each transition is set by an ordered seven of the type [3, 31, 32]:

$Z = \langle\langle l_1, l_n, t_1, t_2, \square, r, M \rangle\rangle$, where l_1, l_n - end, non-empty sets, the elements of which are called respectively input and output positions; t_1 - time in which the transition is activated; t_2 - duration of the active state of the transition; r - transition condition, determining which kernel can pass from its input to its output positions. It is set by an indexed matrix (m x n); M - indexed matrix of capacities of the transition arcs;$\square$ - a boolean expression object specifying whether t_1 can be activated at the moment.

According to K. Atanasov, the creator of generalized nets [31, 32], each network is presented as follows:

$E = \langle\langle A, \pi_A, \pi_L, c, f, \theta_1, \theta_2\rangle, \langle K, \pi_K, \theta_K\rangle, \langle T, t^0, t^*\rangle, \langle x, \psi, b\rangle\rangle$, where where: A - set of all transitions; π_A - function that sets the priorities of the transitions; π_L - function that sets the priorities of the positions; c - function that sets the capacities of the positions; f - function that determines whether a value of the predicates is correct; θ_1 - function, setting the moment of time in which a transition can be activated; θ_2 - function, setting the duration of the active state of the transition; K - set of nuclei; π_K - function setting the priorities of the kernel; θ_K - function that sets the moment of time in which a kernels can enter the GNs; T - time in which the transition begins to function; t_0 - elementary time step of the fixed time scale; t* - duration of OM operation; x is the set of initial characteristics that the kernel may possess when entering the network; ψ - a function that sets a new characteristic of each kernel after it moves its position; b - a function that sets the maximum number of characteristics that a kernel can receive while moving in the network.

1.4.1.2. Theories of generalized networks

Sources [30, 35] discuss the Special Theory of Generalized Net, while sources [4, 33, 34, 79, 84, 98, 99, 100, 101, 131] discuss the General Theory of Generalized Nets, which includes the compilation of algebraic, topological, functional, programmatic and logical aspects. In 1.4.1.3. from the dissertation is described the methodology for building an GN-model. It follows the following steps:

1) Building a static structure of the modeled process;
2) Reflecting the dynamics of the modeled process;
3) Functioning in time of the modeled process;
4) Necessary data for the modeled process.

The ready GN-model can be used both for simulation of the modeled processes, and for their optimization and management.

In order to use the GN model for process simulation, it is necessary to define random functions that set the correct values of the predicates of the conditions and the values of the time parameters of the process. Simulations of simulated processes can be obtained through simulation.

1.4.2. Fuzzy and intuitionist fuzzy sets

1.4.2.1. Fuzzy sets

Here is a definition of a fuzzy set, as a set, for each of the elements to which a degree of affiliation is defined. The degree of affiliation represents a number from the interval [0, 1].

1.4.2.2. Intuitionist fuzzy sets

In 1983, Prof. Krassimir Atanasov summarized the concept of fuzzy set, defining the concept of ***intuitionist fuzzy set*** over an empty universe E. This was done using a second characteristic function related to the addition of the set to the universe, called function of non-affiliation. Thus began a new direction in mathematics, known as Intuitionistic fuzzy set theory, which expanded the theory of fuzzy sets [130] in the search for multifaceted applications and developed in parallel with the same.

1.5. Conclusions to the first chapter

The following conclusions can be drawn from the analysis of cloud technologies and the possibilities for their application in defense:

1. Analyzing the types of cloud technologies, it was found that PaaS (Platform as a Service) is suitable for building a cloud system for collaboration for the needs of defense, as it provides sufficient computing resources, reliability and efficiency.
2. From the analysis of cloud types, the private cloud is preferable for the needs of defense, as it cannot be used by external users without permission to access and offers a high level of security.
3. The analysis of cloud technologies shows that their use can reduce costs by reducing resources and time.
4. For the analyzed software tools and platforms, MS Sharepoint, GoToMeeting, Team Viewer, MS Teams, Webex, as well as Skype for business are considered suitable for use in building a cloud environment for collaboration, as they offer appropriate functionalities for building collaboration environment.
5. The tools of generalized networks and the theory of intuitionist fuzzy sets can be used to build mathematical models of cloud environments.

As a result of the analyzes, the **OBJECTIVE OF THE CURRENT WORK** can be formulated: On the basis of cloud technologies and architectures to propose appropriate models for building a communication and information environment for collaboration work to support the management process for the needs of defense.

To achieve this goal, the following **MAIN TASKS** are set:

1. To analyze the possibilities of modern cloud technologies and software products that are suitable for building communication and information environments for collaboration work for access to IT services and resources;

2. To propose models of cloud architecture for building a communication and information environment for collaboration work of officials;

3. To make a proposal (option) for building a cloud communication and information environment for collaboration work of defense officials.

CHAPTER TWO
MODELS FOR BUILDING COMMUNICATION AND INFORMATION ENVIRONMENTS FOR COLLABORATION

2.1. Cloud models for building a communication and information environment for the needs of defense

The analysis of the platforms for collaboration work in the first chapter can determine the functionalities that a collaboration environment must contain. They depend primarily on the communication and information services of the organizations for which they will be used. For example, remote work requires a collaborative environment to support video conferencing, the ability to chat, record online meetings, manage and share documents, and more.

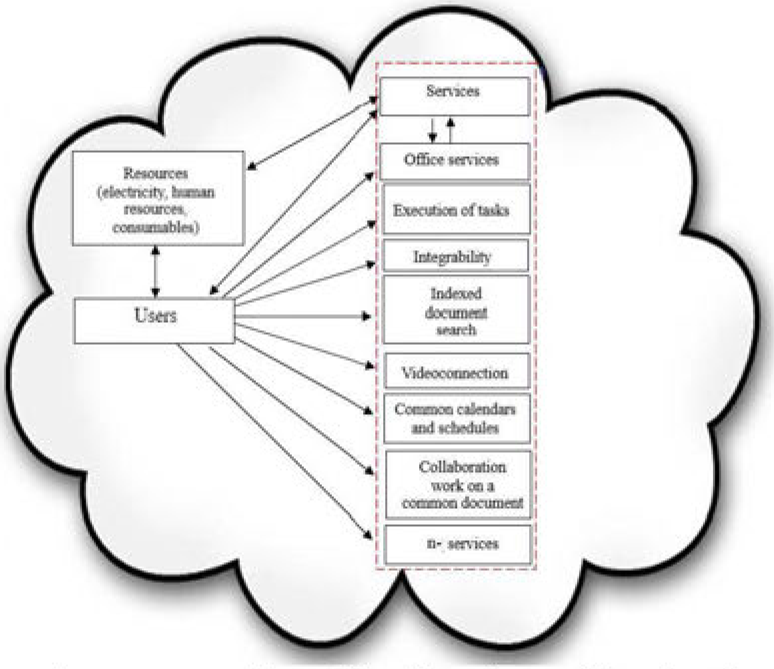

Fig. 2.1. Schematic representation of the functions of the cloud environment for collaboration work for the needs of defense

For collaboration work in a cloud environment, it is necessary for all participants in the process to work together in sync. Figure 2.1 shows the relationship of participants (users, resources and services) for the implementation of such a process. The analysis made in the first chapter shows that the tools of generalized nets can be used to present the processes for building a cloud environment for collaboration work. Through them, many real processes from a wide range of applications can be easily and thoroughly presented.

2.2. Generalized net models of cloud environments for collaboration

2.2.1. Statement of the general model

The Cloud Environment (CE) can be represented by this way:

$$CE = < Su, Se, P >, \quad (2.1)$$

Su - entities involved in the process of providing (technical specialists, administrators) or using (users) of the cloud environment for work, such as Su = $\{X_1, X_2,\ldots, X_m\}$, where X_i are determining (essential) their characteristics;

Se - means for building the environment for collaboration work (technical, information, communication, resource, etc.), through which the cloud environment is built and functions, such as Se = $\{Y_1, Y_2,\ldots, Y_n\}$, where Y_j are their determinants characteristics;

P - procedures (technologies, requirements, criteria, standards, knowledge, etc.) for building, maintaining and using the cloud environment for collaboration such as P = $\{Z_1, Z_2,\ldots, Z_q\}$, where Z_l are their main characteristics.

Each of the individual characteristics X_i, Y_j and Z_l is represented by triplets (r_k, μ_k, π_k), where r_k is the k-th characteristic, μ_k is an estimate of the importance of this characteristic, and π_k expresses the degree of fluctuation about its importance.

The choice of a solution for building a cloud environment for collaboration work is related to determining the complex assessment $h(c_i^a, c_j^b)$ for its individual structural components, as follows:

$$h(c_i^a, c_j^b) = \lambda^{int} h_{int.}\, \gamma^{Ca}(p_a^b) + \lambda^{s}.h_s + \lambda^{e}.h_e \quad (2.2)$$

$h(c_i^a, c_j^b)$ - complex numerical value for determining the possibilities for integration between components c_i^a and c_j^b;

h_{int} - assessment of the possibilities for integration of the two components;

h_s - assessment of the chosen integration strategy, obtained from similar other solutions;

h_e - expert assessment received by experts in the field;

λ^{int} - coefficient for determining the "weight" of the assessment for the integration of the two components;

λ^{s} - coefficient for determining the "weight" of the assessment for the selected strategy;

λ^{e} - coefficient for determining the "weight" of the expert assessment.

The parameter $\gamma^{Ca}(\rho_a^b)$ is an activating function for component c_a, according to the formula:

$$\gamma^{Ca}(p_a^b) = 1/\left(1 + e^{P_b^a}\right), \quad (2.3)$$

where: $\rho_a^b = f(\mu_r(a), \nu_r(a))$ is an estimate of how suitable component a is for integration with component b, $\mu_r(a)=[0,1]$ and $\nu_r(a)=[0,1]$ show respectively the degree of fulfillment and non-fulfillment of the requirements ra for integration of component a with component b.

The result of the function $\gamma^{C_a}(\rho_a^b)$ is always in the range [0,1] and according to the obtained value (whether it is closer to 0 or to 1) it can be determined whether the component cia can be integrated with the corresponding component b. In the case of values around the middle of the interval, the integration between the two components is assumed to be indeterminate.

2.2.2. Generalized net model of building a communication and information environment for collaboration

In the dissertation work a block diagram of the process for building a communication and information environment for collaboration is made.

On the basis of the developed block diagram (2.2.2.1 of the dissertation) a generalized net model has been developed.

The scheme of the model of building a communication and information environment for joint work is shown in fig. 2.4, and the description is as follows:

$E = \{Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_7\}$, where:

Z_1 - analysis of means for building a communication and information environment for work;

Z_2 - comparison and selection of the appropriate means for the purpose;

Z_3 - planning the required configuration (architecture);

Z_4 - evaluation of the proposed configuration (architecture);

Z_5 - choice of target configuration (architecture) of the built environment;

Z_6 - check the selected configuration (architecture);

Z_7 - implementation of the selected configuration of communication and information environment for work.

The kernels are: α - subjects (technical persons - specialists, administrators, users);

β $\{\beta', \beta'', \beta'''\}$ - means for construction (products, tools, equipment, material resources) (β'- communication and information means, β''- technical, β''' - resource provision);

γ - construction procedures (criteria, requirements, standards, technologies, etc., including target conditions to be achieved);

ι - information (knowledge, expertise, good practices, etc.);

δ - estimates (intuitionist fuzzy set).

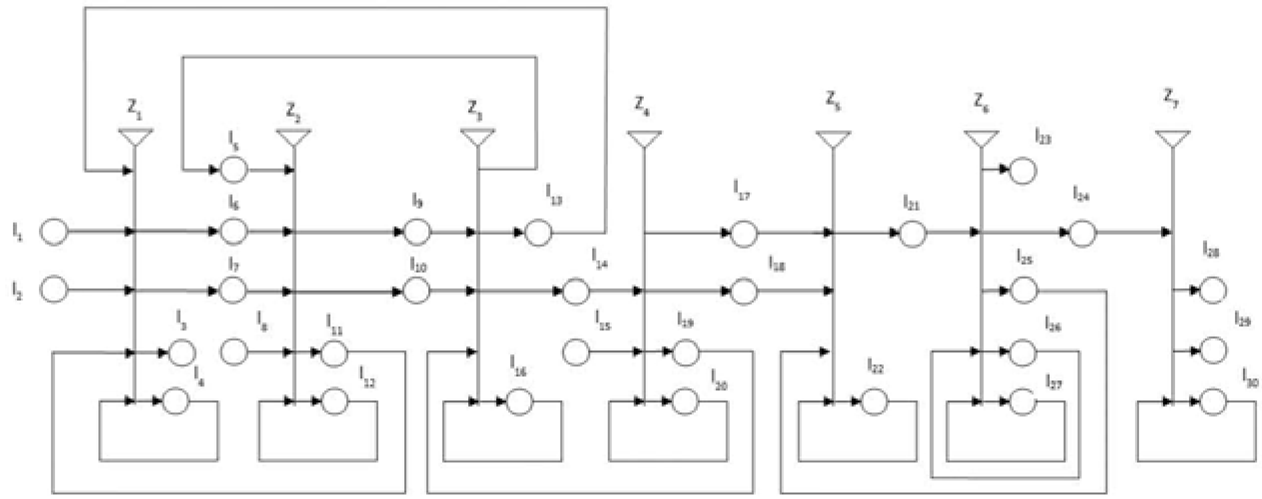

Fig. 2.4. Generalized net model of a process for building communication and information environment

2.2.3. Generalized network model of video communication in the environment for collaboration

In the dissertation work a block diagram (2.2.3.1.) Of the process for creating a video-communication connection in an environment for collaboration is made.

The generalized network (Fig. 2.6) contains the following set of transitions:

$E = \{Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_7, Z_8\}$, where the transitions describe the following processes:

Z_1 - configuration of an administrator profile in the platform;

Z_2 - configuration of an ordinary user profile;

Z_3 - creating a group of users;

Z_4 - setting user rights;

Z_5 - scheduling an online meeting;

Z_6 - invitation of selected users to the meeting (by phone, email or chat);

Z_7 - event management;

Z_8 - termination of the communication and information online connection.

The following kernels are running on the network:

- α - kernels that represent the users of communication services (administrators, ordinary users without administrator rights);

- β - kernels representing separate groups of users (groups are divided, depending on the rights of the individual users that make up the groups);

- γ γ ', γ' ', γ' "} - kernels representing communication links (γ'-chat messages, γ " - phone, γ " '- email).

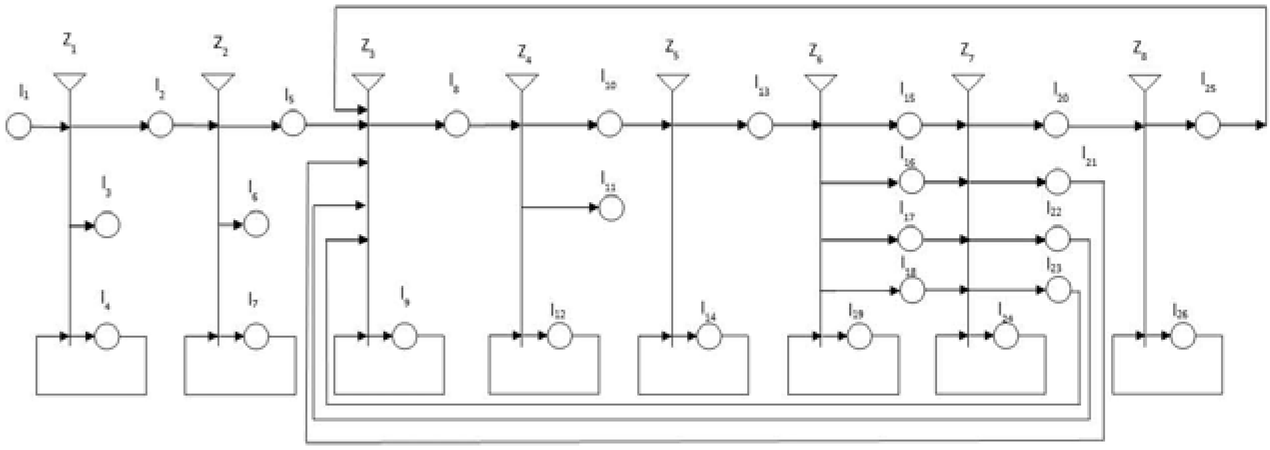

Fig. 2.6. Generalized net model of video communication in a collaborative environment

2.2.4. Generalized network model of cloud infrastructure for building an environment for collaboration

In the dissertation work a block diagram (2.2.4.1) of cloud infrastructure for building an environment for collaboration is made.

The scheme of the model realized with generalized net E is shown in fig. 2.8, the description being: $E = \{Z_1, Z_2, Z_3, Z_4\}$, where:

Z_1 - generating an information service request;

Z_2 - modeling the functioning of the communication and information node;

Z_3 - modeling the operation of the data center;

Z_4 - system monitoring and analysis and results.

The generalized net model (fig. 2.8) consists of 4 transitions, 22 positions and 5 types of kernels.

The kernels for the whole process are:

α-entities (users) initiating service requests with the following characteristics: X_α $(e^{\alpha}_{p,1}, e^{\alpha}_{p,2}, ..., e^{\alpha}_{p,i}, ..., e^{\alpha}_{p,k})$, where $e^{\alpha}_{p,1}$ is the evaluation of the i-th type of service by pi $(i \leq k)$ evaluation parameters;

β-requests, services, results, with the following characteristics: X_β $(e^{\beta}_{q,1}, e^{\beta}_{q,2}, ..., e^{\beta}_{q,i}, ..., e^{\beta}_{q,s})$, where $e^{\beta}_{q,i}$ is the evaluation of the i-th parameter of qi $(i \leq s)$;

δ-entities (users) that receive requests from the system, with the following characteristics: X_δ $(e^{\delta}_{d,1}, e^{\delta}_{d,2}, ..., e^{\delta}_{d,i}, ..., e^{\delta}_{d,s})$, where $e^{\delta}_{d,i}$, is an estimate of the i-th type of service by w $(i \leq n)$, initiating service requests;

υ-resources (electricity, human resources, consumables, etc.), necessary for the proper operation of the system or for its restoration (improvement), with the following characteristics: X_ι $(e^{\iota}_{v,1}, e^{\iota}_{v,2}, \ldots, e^{\iota}_{v,i}, \ldots, e^{\iota}_{v,m})$, където $e^{\iota}_{v,i}$ is the estimate v $(i \leq m)$; is the estimate of the i-th resource of m required resources of the system;

γ-monitoring of the system, with the following characteristics: X_γ $(e^{\gamma}_{v,1}, e^{\gamma}_{v,2}, ..., e^{\gamma}_{v,i}, ..., e^{\gamma}_{v,m})$, където $e^{\gamma}_{v,1}$ is the i- this parameter of vi $(i \leq m)$ assessment parameters of the state of the system, including opportunities for its normal state and the possibility to improve its functionality (by updating technological solutions).

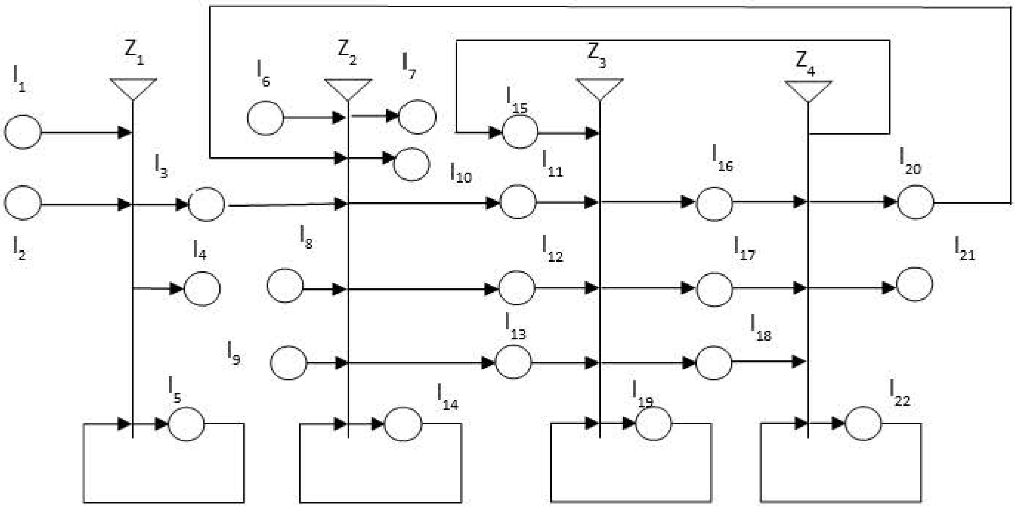

Fig. 2.8. Generalized net model of cloud infrastructure for building an environment for collaboration

2.3. Approach for determining the estimation parameters of the kernel in GN-models

The assessment of the functioning of an object/process is not always accurate. Its determination is to some extent subjective, ie it depends on the person performing the assessment, his understanding and preparation.

In order to analyze their functioning, it is necessary to assess the extent to which it belongs to one or another neighboring state.

To assess the successful operation of individual infrastructure sites reliable sending of a service request, its receipt and fast processing can be used ordered pairs $<\mu, \nu>$ of real numbers ($\mu \in [0,1], \nu \in [0,1]$).

$S = S_1 + S_2 + S_3$ as: S - states in which a given object of infrastructure may fall; S_1 - good condition of the object; S_2 - damaged condition of the object (or its individual modules); S_3 - partially operational condition of the site (or its individual modules).

The degree to which the belonging of an object to any of the states S - is estimated can be expressed by estimating functions of belonging μ_S (O_i) to this state. [21] Estimates can be represented numerically (number in the range [0,1]) or linguistically ("weak", "medium", "strong", etc.). Fuzzy Set Theory and Intuitionist Fuzzy Set Theory are used for this purpose. Fuzzy sets are usually used to model concepts that cannot be precisely defined when describing real systems.

By using Intuitionist Fuzzy Set Theory, the degree of affiliation μ_S of objects/ processes (respectively, the degree of non-affiliation νS) to certain states or to several closely related states can be determined.

In order to compile a complex estimate (linguistic and / or numerical) of a certain object to what extent it belongs (μ_S) or not (ν_S) to a given state (S) it is necessary to transform the estimates μ_S (S_1, S_2, S_3), ν_S (S_1, S_2, S_3) and represented by linguistic quantifiers in numerical values. For example, the degree of affiliation μ_S can be expressed as follows: μ_{Si} (normal) = Q_i, μ_{Sp} (extreme) = Q_p, μ_{Sb} (critical) = Q_b.

The values in the range [0,1] are divided into a number of levels of fuzzy linguistic quantifiers "weak", "medium", "strong" or "low", "medium", "high", "very high", "very low". " etc.).

When modeling the process of building data centers, each transition has a set priority. The conditions for the realization of the events are presented by the presence of cores in the respective input positions.

In the scope of the evaluation {0; 1} the determined parameter has a set condition /value, which is either fulfilled 1 = "yes" or not fulfilled 0 = "no". A possible way to determine indeterminate parameters is through the Theory of Fuzzy Sets or the Theory of Intuitionist Fuzzy Sets [106].

A presentation of the estimates of the parameters of the nuclei in the models presented above is given in Table 2.1.

Table 2.1 Estimation parameters of the kernel in the GN models

Name (of the most commonly used kernels)	**Evaluation parameter / characteristic**		**Precondition**	**Scope of evaluation**
a *subject*	$e^{a}_{p,1}$	Knowledge of the subject area	Possession of the necessary knowledge to work with IT environments, cloud technologies, etc.	*{0,1}*
	$e^{a}_{p,2}$	Information about the conditions of work with the object	Possession of the necessary knowledge (information)	*{0,1}*
	$e^{a}_{p,3}$	Knowledge of the necessary normative documents (standards, methods, methodologies, etc.)	Knowledge of normative documents and knowledge of how to use them	*[0,1]*
	$e^{a}_{p,4}$	Experience	What experience does the person who will perform the process have?	*[0,1]*
Resources				
β *resources for construction*	Products		*Suitable products for work*	*[0,1]*
	Tools		*Suitable tools for work*	*[0,1]*

Name (of the most commonly used kernels)	Evaluation parameter / characteristic	Precondition	Scope of evaluation
	Equipment	*Suitable equipment for work*	*[0,1]*
	Material resources	*Appropriate material resources for work*	*{0,1}*
β^{i} *communication and information*	*Necessary communication and information tools*	*What are the appropriate means of communication and information*	*[0,1]*
β^{ii} *technical*	*Technical means for construction*	*What are the appropriate technical means for construction*	*[0,1]*
β^{iii} *resource provision*	*Necessary resource provision*	*What are the necessary resources*	*[0,1]*
γ *construction procedures*	*Requirements*	*What are the requirements for the construction procedure*	*[0,1]*
	Criterias	*What are the criteria for the construction procedure*	*[0,1]*
	Standarts	*What are the standards for the construction procedure*	*[0,1]*
	Technologies	*What are the technologies to the construction procedure*	*[0,1]*
	Target states	*What are the target conditions for the construction procedure*	*{0,1}*
δ *evaluation*	*Degree of adverse impact*	*What estimates are acceptable*	*[0,1]*

2.4. Conclusions to the second chapter

As a result of the research in this chapter, the following more important conclusions can be drawn:

1. Aggregate networks are a convenient tool for describing the processes of creating and operating cloud collaboration environments, as well as the infrastructure supporting them.

2. The construction of the generalized net model of communication and information environment for collaboration work will provide simulation of the processes of its functioning and will provide an opportunity to play different options for its use.

3. The proposed generalized net model of video communication in a collaborative environment will help to better present the processes for online communication in a cloud environment.

4. The created generalized net model of cloud infrastructure for building an environment for collaboration work is a good basis for building a suitable cloud platform for the needs of defense.

5. The presented approach for determining the estimation parameters of the nuclei in the GN-models gives the opportunity to compile more accurate estimates of their parameters with the application of intuitionistic fuzziness.

CHAPTER THREE
SIMULATION OF GENERALIZED NET MODELS AND PROPOSAL FOR CONSTRUCTION OF CLOUD COMMUNICATION INFORMATION ENVIRONMENT FOR COOPERATION

3.1. Study of generalized network models using the GN-IDE simulation software environment

3.1.1. Brief description of the GN-IDE

After the definition of generalized net by Krassimir Atanasov in 1982, various software tools for their simulation were developed. Some of these developments are mentioned in [25, 105, 106].

GN IDE (Generalized Nets Integrated Development Environment) is software for simulation of generalized net models [27]. It is developed in the Java programming language [55, 65, 74, 88, 95, 102, 103] and can be run on a platform with the Java Runtime Environment (JRE) installed.

As mentioned in [105], the GN IDE provides several different views for process visualization, namely: graphical view, tree view, property view, functional view.

Below are some of the screens generated in the GN IDE simulation of the three GN models.

3.1.2. Simulation of the OM-model of building a communication and information environment for collaboration

Before we present some screens from the simulation of the GN model itself, let's give a brief explanation of the operation of the network.

After the kernel enter the **Z_1 transition** and move through it, only their defining (main, leading) characteristics are evaluated, which are related to the analysis and the task here is to determine which of all existing entities (technicians, administrators, users) and tools (software applications, servers and technical "tools") are suitable (according to some set minimum threshold of their assessments) to be used to achieve the goal - creating a working environment for collaboration.

In transition Z_2, a comparative evaluation of the received selected kernel is performed, which are evaluated for the second task - not just to determine whether each tool or entity is suitable to achieve the goal, but whether, when cooperating with each other, they can achieved a working configuration. This may include: identifying the appropriate professionals, selecting the necessary collaboration software, identifying the required physical servers, and more infrastructure through which the required cloud infrastructure can be realized in a collaborative environment.

Compliance with the requirements in the conditions of a given transition means that the arriving kernels must meet the needs - the implementation of the required IT services or, in other words, their numerical estimates to be above the minimum threshold for the specific task, ie. in this case these are: 0 - 0.3 do not correspond; between 0.3 - 0.6 - partially meet the requirements; over 0.6 - up to 1.0 (incl.) meet the requirements. Values from 0.5 to 1.0 (when simulating the passage of kernel through the transition) and from 0 to 0.4 (when simulating that they do not respond) are used for the simulation.

Limits for the values are set in the information i-kernel and / or in the places of execution of the processes for each transition (for example, for Z_1 - this is related to position l_4, for Z_2 - with l_{12}, etc.).

For the simulation in the model several α-kernels are used (each of them is a separate person - a specialist) and accordingly we can set different values of their individual characteristics X_i, ie. each α-kernel can have different values of its characteristics. The requirements for α-kernel are represented by a vector R (r_1, r_2, ...) of estimates [0,1] (these are actually characteristics of i- kernel and γ- kernel) with which the vector of characteristics of each α- kernel (which is actually a separate candidate). In this way we can work with several α-kernels with different characteristics and in the place of comparison (correspondence) in the given transition to determine which specialist (α- kernel) is suitable for a given task and which is not. It is similar with other kernel, for example with β- kernel. In terms of γ-kernels, they are more like i-kernels, as they "carry" procedures, instructions and other data for the implementation of the built IT environment.

β- kernel entering the Z_1 transition may appear at different times, it is important to be present when needed for analysis and to be evaluated at the time, to be checked whether they are suitable for a given task or not. With regard to α- kernel, they need them (as resources) as well as γ- kernel (as procedures and instructions) in order to build the relevant element of the IT environment in which all cores need to be involved, like humans (α- kernel), of course, are the drivers in the process. We can summarize that after the β-kernel enter position l_4, they are checked for their necessary characteristics (similar to the check for α- kernel) in order to continue their movement in the GN network.

In simulation, α- kernel can be divided into two types - α' kernel (specialists, administrators) and α'' kernel (users), which is only a conditional division and is another way of representing the process.

The necessary configuration (architecture) is planned for the **Z_3 transition**. There are α-, β-, γ- and ι-kernels for the process of planning the architecture of the communication and information environment.

In the Z_4 transition, the proposed architecture is evaluated. In this transition enter δ-kernels (intuitionist fuzzy estimates), with characteristic X_ϑ–-estimates of the proposed configuration (architecture) of the communication and information environment. This also includes α-, β-, γ- and í-kernel, which configure architectures with common estimates above the allowable lower threshold, successful architectures that are evaluated to make the right choice.

In the Z_5 transition, a choice is made of the target configuration (architecture) of the built environment, based on the integration of the respective participating kernels, necessary for its creation.

Transition Z_6 checks the selected configuration, ie a prototype of the selected configuration (architecture) of the environment is tested. The transition is occupied by kernels that form a successful configuration of the architecture of the environment, performing a process of testing the configuration of the environment using a prototype. If the test is negative, a new configuration of the environment is selected, then the prototype configuration is tested again and so on until a successful configuration is found or the specified number of possible or set iterations is reached.

Transition Z_7 shows the implementation of the selected configuration of communication and information environment for work. In the transition there are kernels that form the successful configuration of the architecture, as well as kernels involved in the construction (implementation) of the successful configuration (architecture). The process ends with the selection of the most appropriate configuration of communication and information environment for work.

The following figures (3.1, 3.2, 3.3, 3.4) show the entry and movement of kernel in the process of building a communication and information environment for collaboration.

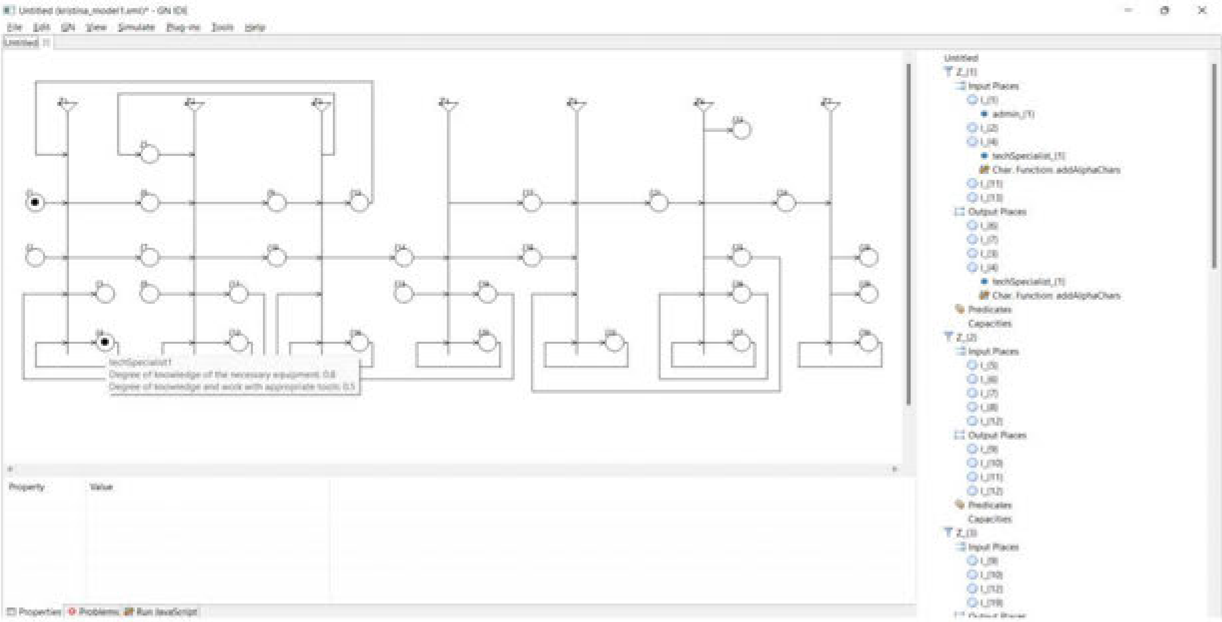

Fig. 3.1 Entry and movement of the α-kernels in the initial transition of the GN-model

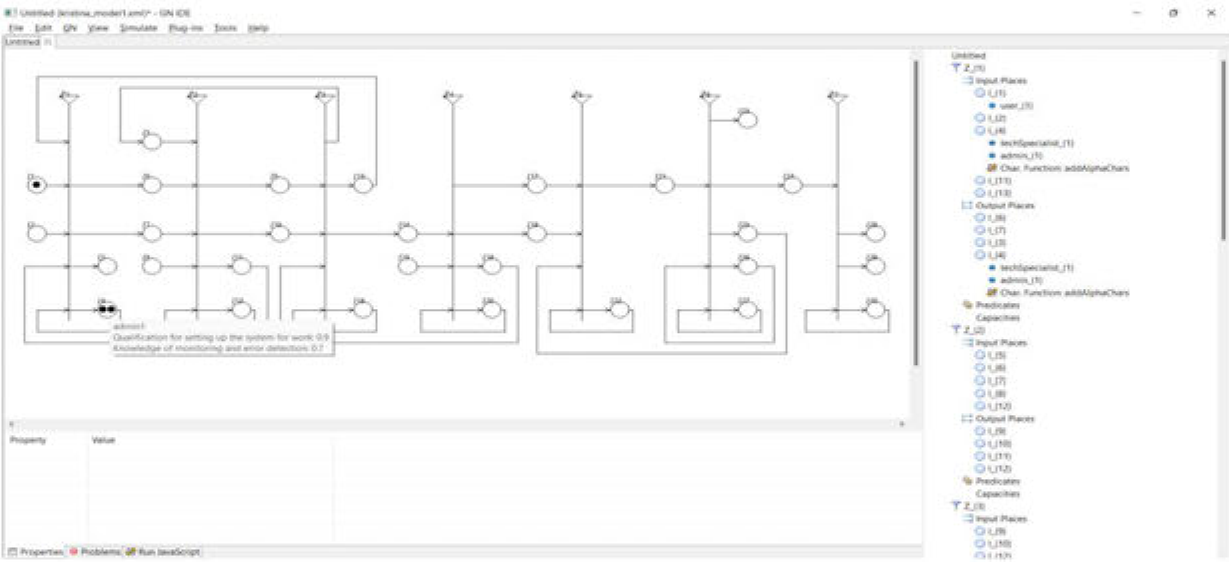

Fig. 3.2 Movement of the α-kernels (administrator) in transition Z_1

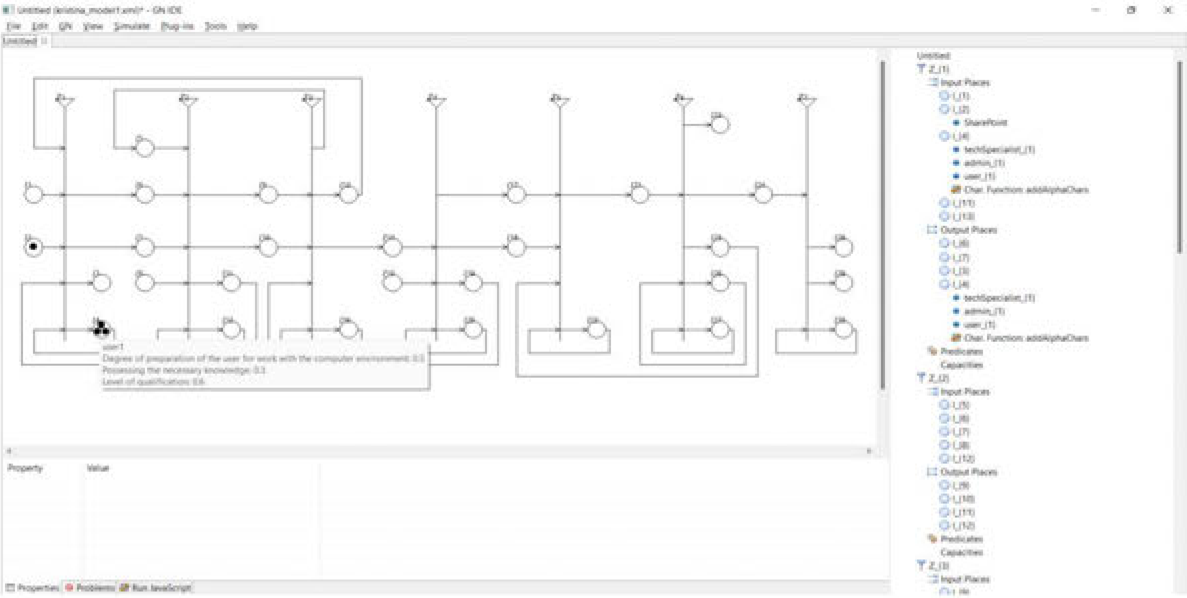

Fig. 3.3 Movement of α-kernel (user) when using the MS SharePoint platform

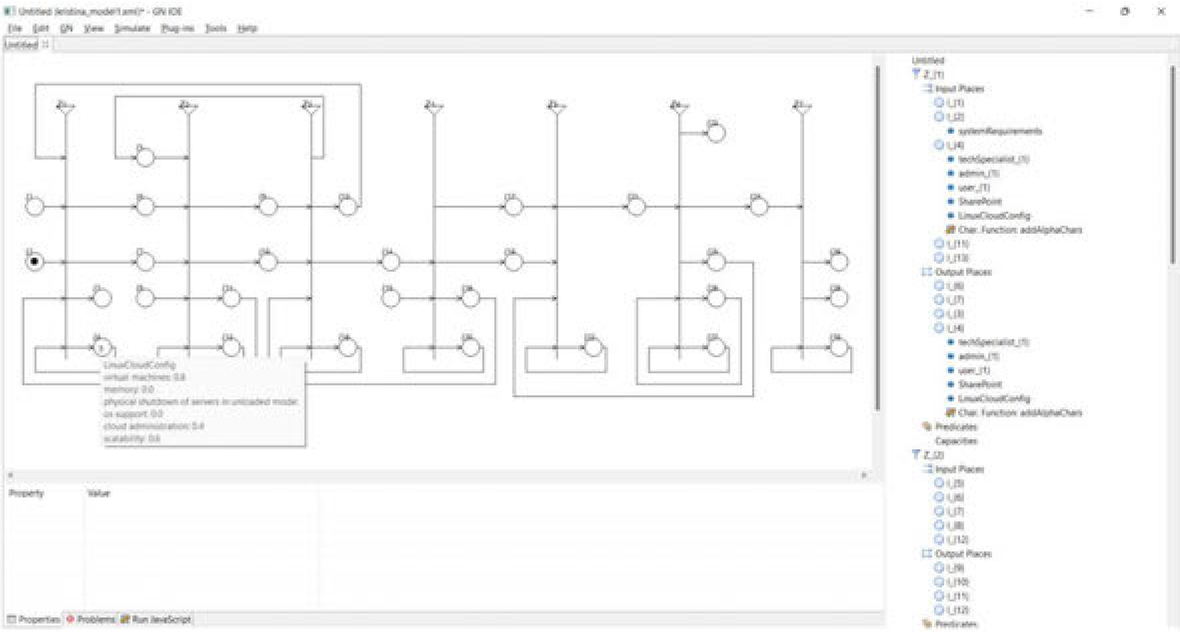

Fig. 3.4 Entry of the β-kernels in the initial position of the GN-model

3.1.3. Simulation of the GN-model of video communication in a collaborative environment

In the previous model, **the Z_1 transition** includes α-kernels, which represent the users of communication services (administrators or ordinary users without administrative rights). Only the main features of these kernels, which are related to the task of creating an event in a collaborative platform, as well as the verification of the possibility of configuring an administrator profile for this event, are evaluated.

During the Z_2 transition, α- and β-kernels arrive, after an analysis has been made and it has been determined which ones can take the role of administrators and which of them will drop out if they cannot be assigned an administrator profile.

The process of determining whether the received cores meet the transition conditions means that they have the necessary characteristics to implement the required IT services. The estimates for this are analogous to those described in item 3.1.2 (0 - 0.3 - do not meet, between 0.3 and 0.6 - partially meet the requirements and over 0.6 - to 1.0 (incl.) - fully meet the requirements).

The simulation uses three γ-kernels in the model, each of which represents a different type of communication links: γ'-chat messages, γ ”- phone, γ“ ”- email. For each of these nuclei we can set different values of their individual characteristics $X\gamma$. The requirements for γ-nuclei are also presented as above by vector R (r_1, r_2, ...) from estimates in the range [0,1].

The β-kernel entering the network fall into position l_4, l_{10}, checking that they have the necessary characteristics (lines) to continue inwards to the other transitions.

A Z_3 transition creates a group of users. Пo-kernels enter there as administrative users.

In the Z_4 transition, user rights are set. β -kernels go through this transition, which models users with given rights. These kernel must be analyzed and, if they meet the relevant requirements, given (or not) the right to participate in the meeting.

The Z_5 transition simulates the scheduling of the online meeting itself.

In transition Z_6 is sent an invitation to the selected users for the meeting by phone, email or chat message. In this transition enter γ-kernels representing communication links (an invitation to participate in an online communication link is made and a response is accepted from the invited users.

In the Z_7 transition, the communication event itself is controlled, there is a process of verification for the implementation of communication and information connection, as well as recording of the online meeting.

In the transition Z_8, the online communication and information meeting is terminated.

Figure 3.8 shows the home screen of the simulation of the event creation process in video communication in a collaboration environment.

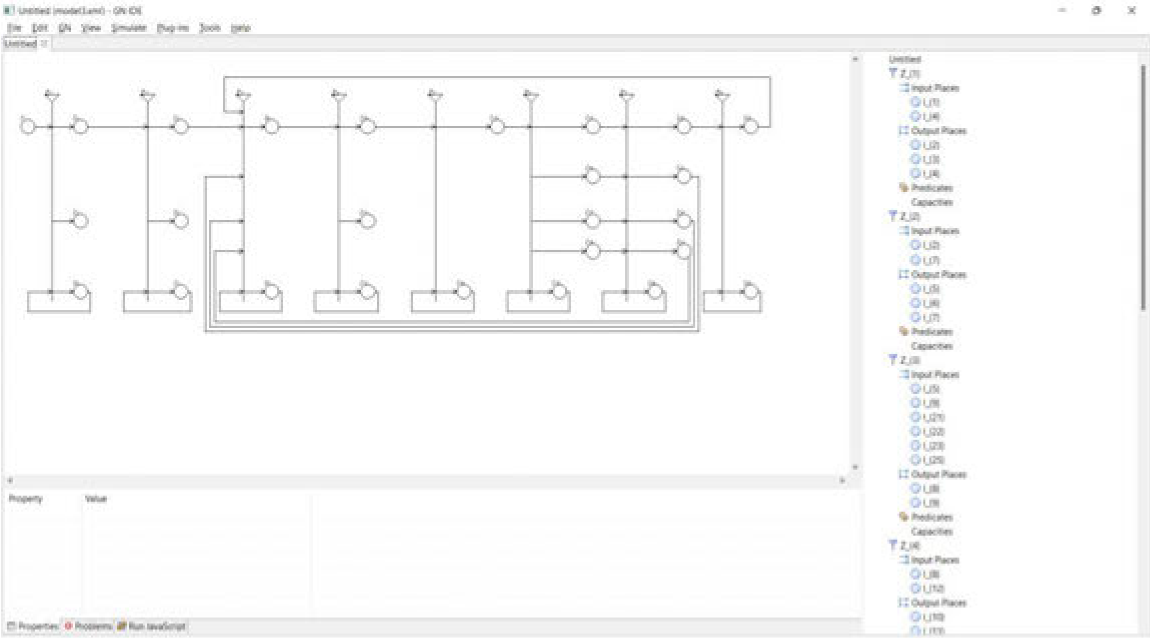

Fig. 3.8 Screen of the simulation of the process for creating an event in video communication in a collaborative environment

3.1.4. Simulation of the OM-model of the cloud infrastructure for building an environment for collaboration

In this simulation, the generation of an information service request takes place at the **Z_1 transition** where the α- and δ-kernel arrive. Estimates are determined only for those of the main characteristics of the nuclei that are related to the purpose of the task. In this transition, the system is in service standby mode.

In transition Z_2, the processes of functioning of the respective communication and information node are modeled in three modes of operation: normal, extreme and critical.

The Z_3 transition simulates the operation of the cloud data center (physically located after KIV). The i- and δ-kernels move there, which ensure the implementation of the information process and the data center, in the different modes of operation of the system.

In the Z_4 transition, cloud infrastructure is monitored and analyzed. In this transition, δ-kernels enter, which model the adverse effects of the environment on the data center.

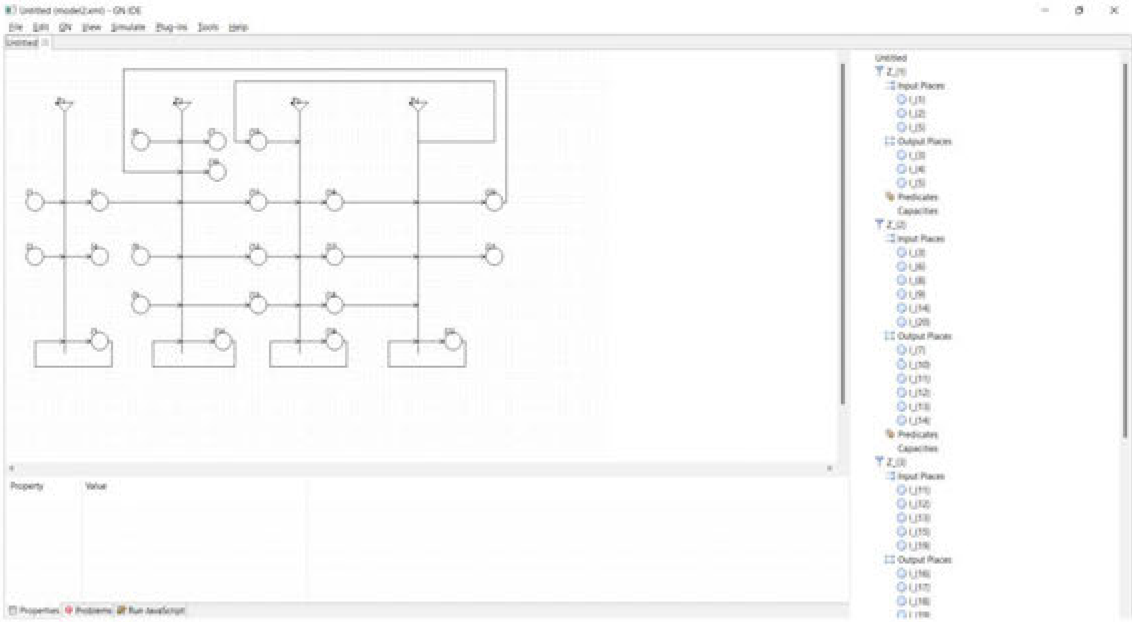

Fig. 3.10 Screen of simulation of the GN-model of the cloud infrastructure for building an environment for collaboration work

3.2. Approach to building a cloud communication and information environment for collaboration work for the needs of defense

An approach is given for building a cloud communication and information environment for collaboration work for the needs of defense, which the author (co-author) considers in [60].

Its essence is that the process of building a cloud environment for collaboration can be represented in three main aspects [62]: technical, systematic and functional.

Technically, the collaboration environment is based on the use of a High availability server architecture, which includes two active high-speed servers and a shared disk space (array). The advantages of this type of architecture are the provision of high reliability, dynamic load distribution, active mode of operation on both servers.

Systematically, the cloud collaboration environment includes information subsystems related to the functional responsibilities of officials.

Functionally, the communication and information environment provides some basic information and communication services: common information portal, work with electronic documents and organization of document flow, video and audio conference between participants in the discussion, preparation of mathematical and simulation models of processes, joint work on common electronic document and others.

By dividing the process of building the cloud environment for collaboration work of individual components, better differentiation of individual activities is achieved, following the real direction of need: from the necessary services of officials, through the relevant subsystems from which they are provided to the technical base which provides them.

3.3. Proposal for building a prototype of a cloud communication and information environment for collaboration work for the needs of defense

3.3.1. Conceptual model of a cloud environment for collaboration

The cloud environment for collaboration is a set of technical means, communication and information tools and software. Its functioning also requires people - specialists, administrators, users. In addition, information needs to be processed, summarized and exchanged.

The conceptual model of the cloud environment for collaboration (Fig. 3.12) is based on the proposed way to build a system of data centers and can be presented as a set of:

- data centers (A, B, C, ();
- computer networks;
- computer devices (PC_{a1}, PC_{a2},… PC_{b1},…, PC_{c3});
- information and communication services;
- administrators and users.

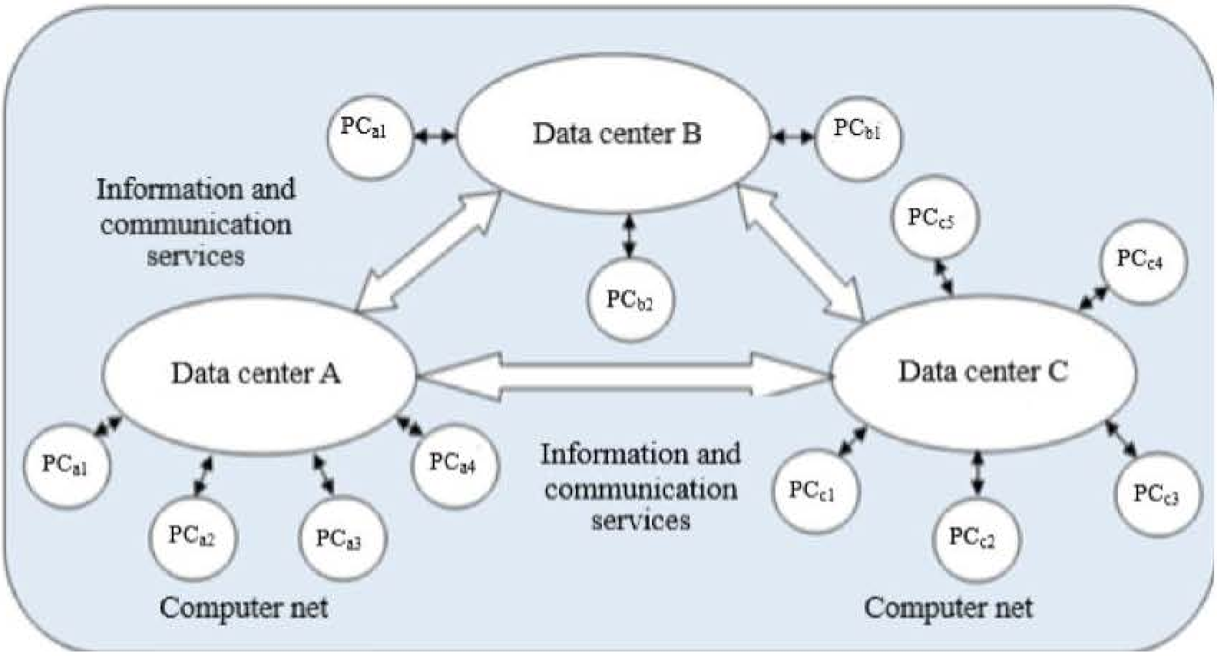

Fig. 3.12 Model of cloud components for collaboration

Physical, logical and informational connections are made between the individual components of the cloud environment for collaboration. Physical connections determine communication connectivity, logical connections are provided by the common cloud environment, and information connections - through data exchange.

3.3.2. Model for realization of a cloud communication and information environment for collaboration work

The cloud communication and information environment for collaboration must be built on a system of centers that provide their adjacent users with IT services and synchronize the processed data. One of the great advantages of the cloud environment is to reserve both the services provided and the information that is processed and stored. For this purpose, the physical infrastructure that unites the individual centers, computer devices and networks is used as the basis of the cloud environment for collaboration. As a physical environment, the cloud infrastructure proposed in [7, 8] can be used to build an environment for collaboration.

The model offered here for the realization of the cloud communication and information environment for collaboration work consists of the following components:

- means for creating workspaces;
- tools for group work and for organizing document flow;
- communication and video conferencing tools;
- e-mail tools;
- tools for working with documents;
- messaging and disclosure tools;
- means for working with geographical information;
- tools for modeling and simulation;
- tools for project and project management.

Some of the following software products can be used for each of the individual components of the model: MS SharePoint, WorkZone, Workplace, MS Teams, Skype for business. video communication platforms are: Zoom, FreeConferencing, Google Meet. Platforms focused on e-mail services are: MS Exchange, Zoho Mail, OX App Suite, Roundcube and others. (as the latter is used by the employees of the Institute of Defense "Professor Tsvetan Lazarov").

It is proposed to use ESRI ArcGIS or R Maptools to provide geographic information services.

Through the model presented in this point for the implementation of a cloud communication and information environment for collaboration work, defense officials have the opportunity to use various tools for preparation, acquisition and exchange of documents, searching for information in the database and more. They can work both in the online environment (remotely) and in operating rooms, where they have the opportunity to use means of common communication, such as a video wall of visualization of a common operational picture, a common video conferencing system and more.

In Fig. 3.14 shows a diagram of the main cloud services and products and their possible integration in a collaborative environment.

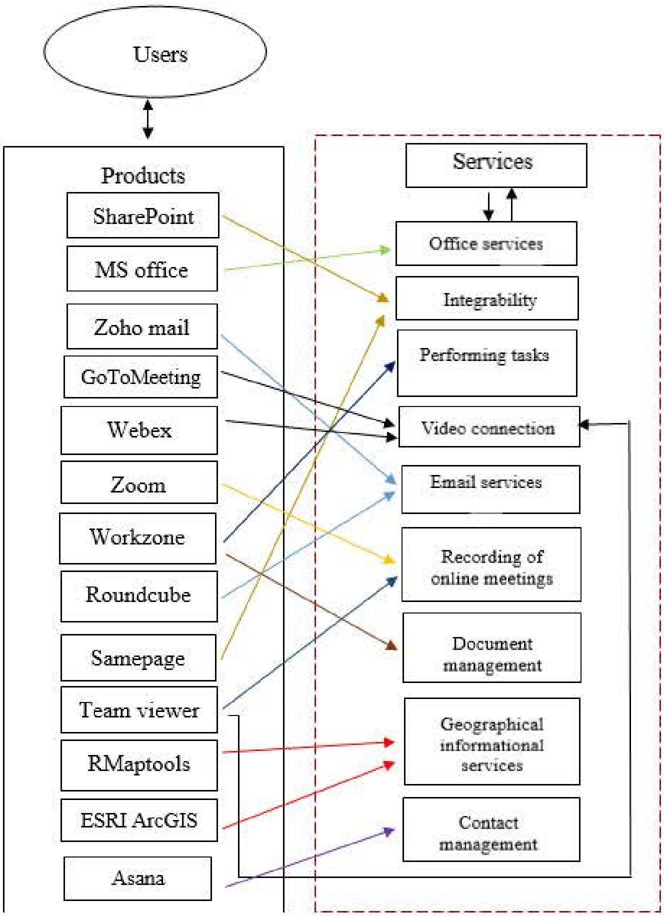

Fig. 3.14 Scheme of basic cloud services and software products, as well as their integration in a common collaboration environment

Figure 3.16 shows a screen from the cloud platform of the "private cloud" of the Institute of Defense.

The various tools for the work of individual officials are launched through the main portal. For each group of them, different information, calculation and other subsystems for work can be defined and included.

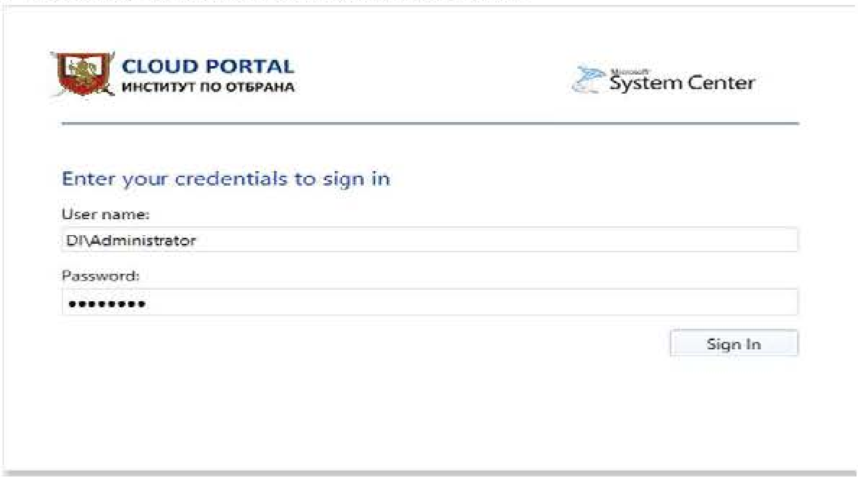

Fig. 3.16 Private Cloud Cloud Platform Screen of the Institute of Defense

Figure 3.18 shows a screen from a collaboration platform that presents a timeline for completing tasks.

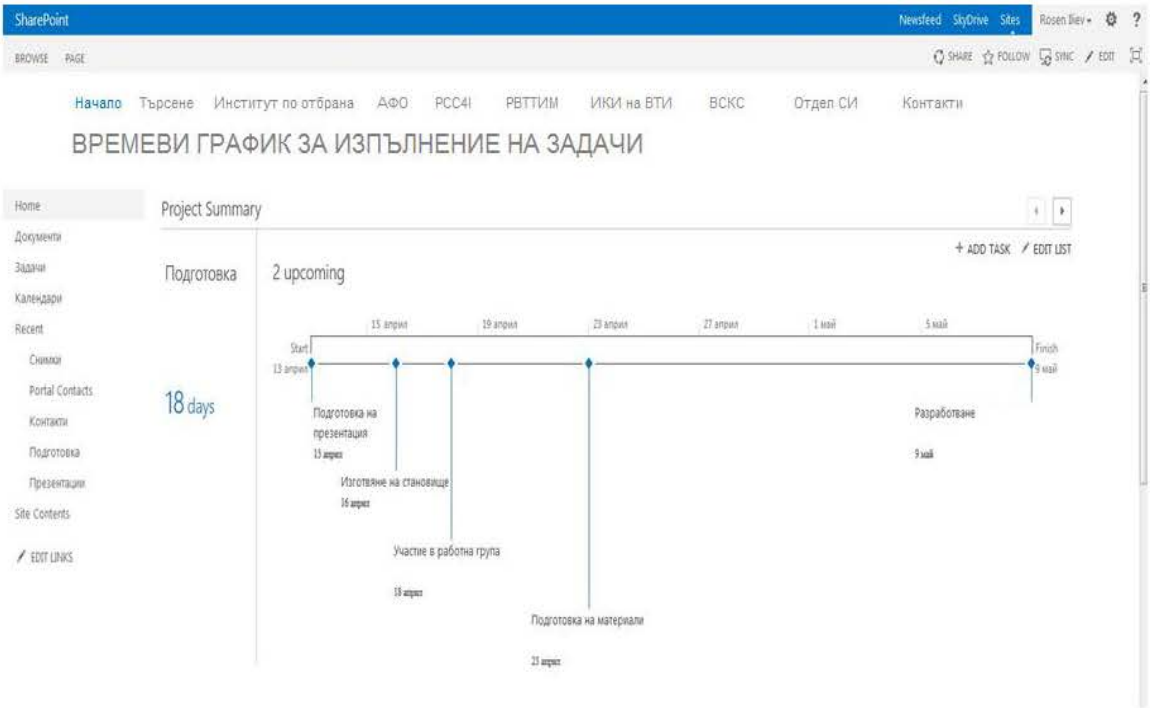

Fig. 3.18 Cloud Collaboration Screen

Building collaboration environments allows for the integration of various software and communication tools to achieve sharing and efficient use of available information and communication resources. The proposed model of the cloud communication and information environment is a web-based platform for integrating various software solutions for individual and collaborative work, for preparation and exchange of documents, for collaboration discussions and many others.

The development of a cloud communication and information environment for collaboration requires a very good knowledge of the work and needs of employees in an organization and offering adequate, sufficiently effective, reliable and easy to use software tools to optimize their activities.

3.3.3. Expected results from the realization of the cloud environment for collaboration work

The construction of the cloud environment based on the model proposed above must be built in such a way as to provide the necessary fault tolerance, flexibility, the ability to increase capacity, pool resources. As a cloud environment, it must provide high access to the information resources used by the user, regardless of his place in the information environment, access to the necessary information resources after authorization, from any workstation in the network.

The results of the implementation of the cloud environment for collaboration will contribute to increasing the efficiency of work by reducing the time for information processing and will minimize the cost of resources, increase awareness in administrative activities and more.

Similar to the models proposed above, a web-based information environment has been set up to work together to assist officials in crisis management, which includes teams from different units, for which websites have been developed to work together with documents, organize different rights to access information resources, providing the necessary services for document management, the ability to conduct video conferencing between different groups of users and others.

3.4. Conclusions to the third chapter

As a result of the research and tests performed in this chapter, the following more important conclusions can be drawn:

1. The GN-IDE (Generalized Nets Integrated Development Environment) software product is a convenient tool for simulating various processes and for testing the performance of the proposed generalized net models for creating cloud collaboration environments.
2. From the simulations of the generalized net models described in the second chapter, it can be concluded that they are a convenient tool for preliminary verification of different options for building a cloud environment for collaboration.
3. The use of the presented approach for building an environment for collaboration activities provides an opportunity to support the analysis of the individual components of the environment and the integration between them in its implementation.
4. The presented conceptual model of a cloud environment for collaboration allows for convenient analysis and visualization of its structure.
5. The proposed model (variant) of building a prototype cloud environment for collaboration can be used to conduct testing and experiments in real operating conditions.
6. The results of the research and simulations of the proposed models are the basis for the practical implementation of a cloud communication and information environment for collaboration activities for the needs of defense.

CONCLUSION AND GUIDELINES FOR FUTURE WORK

The dissertation analyzes the main cloud environments for collaboration, shows which of them can be used to build a cloud communication and information environment for collaboration activities for the needs of defense, created models for building such an environment, and of the process of video communication in it and of its architecture. These models are implemented with the help of generalized net, for which a simulation was performed with the software product GN IDE, and at the end of the third chapter a model (variant) of a prototype for building a cloud communication and information environment for collaboration for the needs of defense.

GUIDELINES FOR FUTURE WORK

From the research on the dissertation it was found that the topic has a wide scope and depth and work on it can continue in some of the following areas:

- the presented generalized net models can be detailed by considering individual sub-processes, thus covering a wider range of tasks related to the construction of cloud architectures for collaboration;

- the scope of the described models can be extended and a detailed comparison of the obtained results with the experiments from the realization of the proposed prototype of a cloud environment for work can be made;

- when describing the parameters of individual kernel and predicates, the tools of the Theory of Intuitionist Fuzzy Sets can be more widely applied, in order to more accurately model the processes of creating cloud environments for collaboration work for the needs of defense.

ACHIEVED RESULTS

In fulfillment of the set tasks and the purpose of the present dissertation the following scientific-applied and applied results have been achieved:

1. An analysis of cloud technologies and architectures has been made and appropriate software products have been proposed to build a collaborative environment.

2. Generalized net models of the process of building a communication and information environment for collaboration work, of the process of organizing video communication and of creating a cloud infrastructure of such a working environment have been built.

3. An approach to building an environment for collaboration activities is presented, analyzing various aspects related to the description of real processes.

4. An approach for determining the estimation parameters of the kernel in the generalized net models is presented.

5. The possibilities for functioning of the proposed models by using the software environment for simulation of generalized GN-IDE networks are studied.

6. A model (proposal) has been made for building a prototype of communication and information environment for collaboration work of defense officials.

LIST
OF THE PUBLICATIONS RELATED TO THE DISSERTATION

[1] Ignatova, K., R. Iliev, Analysis of software tools for collaboration, Proceedings of the International Scientific Conference "ARTDef", Varna, 2021, II-118-II-127.

[2] Ignatova, K., Generalized network model of the process of creating an online communication link in a platform for joint activities, Proceedings of the International Scientific Conference "ARTDef", Varna, 2021, II-218-II-230.

[3] Iliev, R., K. Ignatova. Modeling the process of building an information and communication environment using a generalized network. Proceedings of the International Scientific Conference "ARTDef", Varna, 2021, II-251-II-262

[4] Iliev, Rosen, and Kristina Ignatova. "Cloud Technologies for Building a System of Data Centres for Defence and Security." Digital Transformation, Cyber Security and Resilience of Modern Societies: Springer (2021) 13-24 pp., https://doi.org/10.1007/978-3-030-65722-2.

[5] Ignatova, K., and D. Tsonev, "Integration of Information Resources to Ensure Collaboration in Crisis Management", Information & Security: An International Journal, vol. 46, issue 2, (2020), 141-152 pp., https://doi.org/10.11610/isij.4610.

[6] Iliev, Rosen, and Kristina Ignatova. "Implementation of Cloud Technologies for Building Data Centers in Defence and Security." Information & Security: An International Journal 43, no. 1 (2019): 89-97, https://doi.org/10.11610/isij.4308.

[7] Илиев, Р., К. Игнатова. Софтуерни инструменти за подпомагане на сътрудничеството. Сборник доклади от Международна научна конференция „Хемус 2018“, Пловдив, 2018 г., II-168-II-176.

REFERENCES
(only the sources cited in the abstract)

3. Atanasov, KT, Introduction to the theory of generalized networks, Pontica print, Burgas, 1992.

4. Atanasov, K., E. Sotirova, Generalized networks. Academic Publishing House "Prof. M. Drinov ", Sofia, 2017

7. Iliev R., "Information environments for collaboration", monograph, ISBN 978-619-90024-2-1, Sofia, 2021

8. Iliev R., A. Genchev, Modern data centers (requirements, technologies, construction), Institute of Defense "Professor Tsvetan Lazarov", 2021

11. Cloud infrastructure, https://en.education-wiki.com/3101382-cloud-infrastructure.

12. Cloud computing: nature, advantages, disadvantages and risks, status and prospects, https://www.researchgate.net/publication/331299129_oblacni_izcislenia_cloud_computing_ssnost_predimstva_nedostatci_i_riskove_sstoanie.vi.

15. CIO Cloud Security Challenges, Vol. 7. 2013, pp. 57-59., Http://cio.bg/5600_sigurnostta_na_oblachnite_tehnologii__predizvikatelstvo_pred_it_prilozheniyata_za_otbranata.

16. Program aspect of the theory of generalized networks - optimization of algorithms for implementation, operators for modification of models and applications http://digilib.nalis.bg/dspviewerb/srv/image_singpdff/6ea503b0-54e5-411c-a6bd-a4522268075b.

20. Reference cloud architecture, http://tuj.asenevtsi.com/CNS/SEO%2020.htm, available 27.10.2021

21. Тэрано Т., М. Асаи, М. Сугэно, Прикладные нечеткие системы, Мир, Москва, 1993.

25. Aladjov H., N. Nikolov, P. Georgiev, K. Atanassov. Software for generalized nets. Annual of Technical University, Sofia, Vol. 50, No. 3, 1999, 125-132.

27. Angelova N., M. Todorova, K. Atanassov, GN IDE: Implementation, Improvements and Algorithms, Comptes rendus de l'Acade'mie bulgare des Sciences, Vol. 69, 2016, No. 4, 411—420, ISSN 1310-1331.

30. Atanassov K., Conditions in generalized nets, Proc. of the XIII Spring Conf. of the Union of Bulg. Math., Sunny Beach, April 1984, 219-226.

31. Atanassov K., On generalized nets theory, Prof. Marin Drinov Academic Publishing House, Sofia, 2007, ISBN 978-954-322-237-7.

32. Atanassov, K. Generalized Nets. World Scientific, Singapore, 1991.

33. Atanassov, K., Advances in Modelling & Analysis, C. – AMSE Press, Vol. 46, No. 2, 1995.

34. Atanassov K., Theory of Generalized nets (an algebraic aspect), Advances in Modelling & Simulation, AMSE Press Vol. 1 (1984), No. 2, 27-33.

35. Atanassov, K. On Intuitionistic Fuzzy Sets Theory, Springer, Berlin, 2012.

36. Atanassov, K. Intuitionistic Fuzzy Logics, Springer, Cham, 2017.

40. Brian de Haaff. Cloud computing - the jargon is back! Cloud Computing Journal, August 2008. Electronic Magazine, article available at http://cloudcomputing.sys-con.com/node/613070.

42. Cloud computing – 7 step model of migration (subject code - p16cs41), http://oms.bdu.ac.in/ec/admin/contents/368_P16CS41_2020052602595866.pdf.

51. Ellis, Clarence A., and Simon J. Gibbs. "Concurrency control in groupware systems." Proceedings of the 1989 ACM SIGMOD international conference on Management of data. 1989.

54. Galen Gruman and Eric Knorr. What cloud computing really means. InfoWorld, April 2008. Electronic Magazine, available at http://www.infoworld.com/article/08/04/07/15FE-cloudcomputing-reality 1.html.

55. Guha, Arjun & Saftoiu, Claudiu & Krishnamurthi, Shriram. (2010). The Essence of JavaScript. ECOOP, Lec- Ture Notes in Computer Science. 126-150. 10.1007/978-3-642-14107-2_7. Crockford, Douglas. (2008). [59].

60. Ignatova, K., and D. Tsonev, "Integration of Information Resources to Ensure Collaboration in Crisis Management", Information & Security: An International Journal, vol. 46, issue 2, pp. 141-152, 2020. DOI https://doi.org/10.11610/isij.4610.

62. Iliev, R. Collaborative Information Environments - A Tool for Supporting Management Processes, CIO Magazine, Issue 9, September 2011, pp. 48-49.

65. JavaScript: The Good Parts. [62].

66. Jeremy Geelan. Twenty one experts define cloud computing. Virtualization, August 2008. Electronic Magazine, article available at http://virtualization.sys-con.com/node/612375.

71. Liu, Fang, et al. "NIST cloud computing reference architecture." NIST special publication 500.2011 (2011): 1-28.

74. Mason, Philip. (2020). JavaScript. 10.1007/978-1-4842-5925-2_4.

78. Next Generation Cloud Architectures, https://www.researchgate.net/publication/342743032_Next_Generation_Cloud_Architectures, достъпно 27.10.2021 г.

79. Nikolova, M., K. Atanassov, V. Vasilev, Generalized nets as tools for optimization of real processes, Advanced Studies in Contemporary Mathematics, Vol. 9, No.1, 2004, 47-62.

84. Radeva, V., M. Krawczak, E. Choy, Review and bibliography on generalized nets theory and applications, Advanced Studies in Contemporary Mathematics, Vol. 4, 2002, No 2, 173-199.

85. Rajkumar Buyya, Chee Shin Yeo, and Srikumar Venugopal. Market-oriented cloud computing: Vision, hype, and reality for delivering it services as computing utilities. CoRR, (abs/0808.3558), 2008.

88. Richards, Gregor & Lebresne, Sylvain & Burg, Brian & Vitek, Jan. (2010). An Analysis of the Dynamic Behavior of JavaScript Programs. ACM SIGPLAN Notices. 45. 1-12. 10.1145/1806596.1806598.

95. Severance, Charles. (2012). JavaScript: Designing a Language in 10 Days. IEEE Computer. 45. 7-8. 10.1109/MC.2012.57. [115].

98. Sotirova, E., K. Atanassov, V. Tasseva, An algorithm for constructing of generalized nets on base of case studies. Part 1, Fifth Int. Workshop on GNs, Sofia, 10 Nov. 2004, 1-5.

99. Sotirova, E., K. Atanassov, V. Tasseva, An algorithm for constructing of generalized nets on base of case studies. Part 2, Sixth Int. Workshop on GNs, Sofia, 17 Dec. 2005, 1-6.

100. Sotirova, E., K. Atanassov, V. Tasseva, An algorithm for constructing of generalized nets on base of case studies. Part 3, Seventh Int. Workshop on GNs, Sofia, 14-15 July 2006, 1-7.

101. Sotirova, E., K. Atanassov, V. Tasseva, An algorithm for constructing of generalized nets on base of case studies. Part 4, First Int. Workshop on IFSs, GNs, KE, London, 6-7 Sept. 2006, 125-132.

102. TechTarget, Search Domino, "Groupware", September 2005, Margaret Rouse https://searchdomino.techtarget.com/definition/groupware.

103. Thiemann, Peter. (2005). Towards a Type System for Analyzing JavaScript Programs. Lecture Notes in Computer Science. 3444. 10.1007/978-3-540-31987-0_28.

105. Trifonov T and K. Georgiev. GNTicker – A software tool for efficient interpretation of generalized net models. Issues in Intuitionistic Fuzzy Sets and Generalized Nets, Vol. 3. Warsaw, 2005.

106. Trifonov T., K. Georgiev, K. Atanassov. Software for modelling with Generalised Nets. Issues in intuitionistic fuzzy sets and generalized nets, Vol. 6, 2008, 36-42.

130. Zadeh, L. Fuzzy sets. Information and control, 8&338-353, 1965.

131. Zhao Y., R and Data Mining: Examples and Case Studies, http://www.RDataMining.com, April 26, 2013.