Digital transformation of single information space of a modern university

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Abstract. The article describes the process of development of the single information space of a university on the example of North-Western Institute of management RANEPA under the President of the Russian Federation. The aim of the research is to examine the logistical approach to the development of innovative information space. The composition of the single information space (SIS) is given, the role of its constituent elements is revealed. Special attention is paid to the use of Wi-Fi technologies. The methodology is based on the logistic approach to considering the innovative information educational space as a unified object with special features being determined by the elements included in the system. The principle of the unity of information space consists in possibility of logging into any SIS system by a single account. So, changing of information in one system should lead to change in another, and the exchange of information is realized between the automated systems due to the creation of integration mechanisms based on the universal information gateway, enabling the integrated control system be relevant. The principal conclusion is that single information space creation solves the task of transition from patchwork automation of various fields of activity of the organization to a single integrated approach in building an automated control system based on a single industrial software platform.

1. Introduction

Galés N. L., Gallon R. [1] while considering the system of Integrating Education, AI, and sustainable development growth describe the evolution from traditional pedagogical approach in 1956-2001 period (Bloom’s Pyramid: Remember-Understand-Apply-Analyze-Evaluate-Create) to smart pedagogy covering AI, Smart technologies and Machine learning in 2019 (transformation society). Galés N. L., Gallon R. [2] take into account that pedagogy has been defined as the discipline that deals with theoretical concepts and practical educational approaches. In view of the digitalization according to Galés - Gallon approach a smart pedagogy is based on digital transformation and prove that artificial intelligence provides smart educational agents via technologies the perceptions of reality, cognition, and social interactions. The OECD and UNESCO learning principles for a new pedagogy are focused on the learning space with the advent of personal computers and mobile devices as...
elements that offer a window to the world facing a major paradigm shift, in the form of the fourth industrial revolution, or Industry 4.0. Smart pedagogy concept consists in new technologies and infrastructures enable learning to be personalized to each individual learner. Technological objects metamorphose from tools or environments into personified agents that help teachers evaluate the potential and progress of each learner and might eventually decide for them. The logistical approach is based on the logic of the material, financial and information resources flows [3] in the era of shared economy [4] being an integral part of Internet economy, new economy or web-economy regarding the economy which is considerably based on digital technologies including digital communication networks [5] (the term of “digital economy” suggested by N. Negroponte in 1995 [6]. The specific issues of managing the working spaces in the digital transformation are considered by Kalinina O. [7, 8, 9], with the strategic features being taking into the account by Gutman S. [10] and Brill A. [11]. The assessment of innovative projects in the human resource management system are studied by Rasskazova O. [12]. Kalchenko O. describes the specific of sustainable development of cities regarding the digital transformation on the example of Saint-Petersburg [13]. Some specific issues of managing human capital are examined in the digital era [14-18].

In our opinion the modern look of the educational organization depends on the factors that influence how comfortable is the learning environment for the students. What are these factors? This is availability of a single information educational environment, a university management system, means of communication. In general, all these factors should be unified into a single information space (hereinafter – SIS). It is the SIS that is an indicator of the level of development of an educational organization that affects the efficiency of management and the quality of the educational process. This article presents the most significant achievements of the North-Western Institute of management of the Russian Academy of national economy and public administration under the President of the Russian Federation (hereinafter-RANEPA, St. Petersburg) in the subject area.

There is the largest structural unit of the largest Russian university in St. Petersburg. Based on this, it is natural to assume that many thousands of students require high-quality and effective information space that meets the latest requirements, implementing the functions of access to the electronic information and educational environment, effective control mechanisms implemented in scalable automated information and control systems. The single information space is a complex of automated information systems interconnected by the purposes of functioning and principles of data processing. One of the main tasks to be solved at SIS creation is the task of transition from patchwork automation of various fields of activity of the educational organization to a single integrated approach in building an automated control system based on a single industrial software platform.

Logistical development of innovative information space consider building the SIS on the basis of a universal software platform with a set of well-tested industrial software modules used, which made it possible to use not only its standard solutions, but also to refine and adapt them to the business processes existing in RANEPA in St. Petersburg, as well as to develop own systems with subsequent integration with existing solutions.

Many years of experience in the subject area allows us to state the fact of a significant duration of the process of building the SIS, which is due to the volume and variety of business processes of RANEPA in St. Petersburg, and the complexity of the adaptation of standard solutions. [19]

2. Materials and methods
Structurally, the information space can be divided into hardware and software components. The hardware part consisting of: server and peripheral equipment, local area network and computers, access control and telephony systems form the technical infrastructure of RANEPA in St. Petersburg.

The software part consisting of: functional software modules of automated control systems of administrative operations management, automated information systems, electronic information-educational environment (hereinafter – EIOS) and network resources that form the software infrastructure of RANEPA in St. Petersburg.
Undoubtedly, for a student, the main role is played by the electronic information and educational environment, including electronic information and educational resources, as well as a set of information and telecommunication technologies, appropriate technological means ensuring development of educational programs (hereinafter – EP) in full regardless of their location.

EIOS provides: comprehensive training and methodological support of ongoing OP; continuous access for students to educational resources; the conditions for independent work of students; conditions for e-learning usage in EP realization; the possibility of using e-learning and distance educational technologies (further – EL and DET) in EP realization; open informing of the interested participants on educational process and learning outcomes of the EP realization.

With the help of EIOS the following problems are solved:

- Provision of access to curricula, disciplines work plans (modules), practices, publications of EBS specified in the working programs;
- Provision of registering of the course of educational process, the results of interim assessment and EP realization;
- Conduct of all types of classes, procedures for assessing the results of training, realization of which is provided with the use of EL and DET;
- Formation of the student’s electronic portfolio, including archiving of a student's works, reviews and assessments of these works by the participants of the educational process;
- Interaction between the participants of the educational process, including synchronous and (or) asynchronous interaction through the Internet;
- Ensuring access of students and employees of RANEPA St. Petersburg regardless of their location to electronic information resources and electronic educational resources through the use of information and telecommunication technologies and services;
- Ensuring the individualization of the educational trajectory of the student;
- Improvement of the efficiency and quality of the educational process in RANEPA St. Petersburg;
- Provision of mechanisms and procedures for monitoring the quality of the educational process;
- Ensuring information open access of the Russian Academy in St. Petersburg.

EIOS includes:

- Official site;
- Learning and content management systems (LMS, CMS);
- Electronic library system;
- Personal accounts of students;
- Portfolio of students;
- System of electronic testing;
- Electronic support system for training courses;
- Reference and legal system;
- Other structural components.

EIOS components contain operations instructions for students, teachers and staff, located in the reference sections of the respective components.

EIOS components use open information formats (HTML, XML, SCORM, etc.), which is a flexible way of data exchange both within RANEPA networks in St. Petersburg and on the Internet.

The software and hardware base of RANEPA St. Petersburg represents the specialized infrastructure including the set of software and hardware located in the campus, as well as home workstations of end users, telecommunication channels and the network equipment for ensuring interaction of participants of educational process, including the specialized systems providing usage of remote educational technologies and e-learning.

EL and DET systems contain an information security system, protection protected from tampering and intrusion attempts by internal access authorization systems and system access logging. All systems users are given a personal login and password generated on the basis of the application.
Hardware and software base is a network of specialized classrooms located on the training sites of RANEPA in St. Petersburg, which include:

- Multimedia lecture halls;
- Computer classes;
- Specialized audiences for webinars, equipped with modern computer facilities and multimedia equipment (audio and video system, etc.);
- Reading rooms of the libraries equipped with computer and multimedia equipment, with access to any information resource, including access to full-text teaching materials in electronic library systems.

The software infrastructure of RANEPA in St. Petersburg today, includes a significant number of automated systems that, in general, meet the requirements and solve the necessary profile tasks. However, the main problem in this area is achievement of complete unity of its member systems. In other words, there should be no need for the users to work in multiple systems to process identical information.

In accordance with the logistical concept of single information space development the smart pedagogical task calls for implementation of system theoretical research. The logistical approach to the development of innovative information space enables to realize the following complex solution. Modification of information in one system should lead to change in another. But the principle of the unity of information space – possibility of logging into any SIS system by a single account, we managed to implement through creation of integration mechanisms based on the universal information gateway, through which the exchange of information is realized between the automated systems of the Institute and the integrated automated control system of RANEPA, which is located on the servers of the main campus. In addition, in order to implement a single mechanism for entering the SIS, a campus map was introduced.

In our opinion, the presented structure of the University SIS is quite effective, scalable in the sphere of information systems development and universal in terms of integration mechanisms. But it should be noted that the basis for its effectiveness is the use of modern information technologies and technical solutions, among which, first of all, the technology of the communication network deserves attention.

One of the priority areas, which allowed to bring the SIS to the modern level of development, to improve the image of the Institute, to make it more attractive and convenient for the future students, students and the staff – is construction of a wireless Wi-Fi network. Equipment of all buildings of the Institute with the wireless Wi-Fi network has completely solved the problem of availability of the single information space elements for students and staff of the Russian Academy in St. Petersburg, when staying in any campus building when using their personal devices.

Let us consider the process of building of a wireless network and analyze its effectiveness and impact on the educational process.

Implementation of the project of Wi-Fi network construction in RANEPA in St. Petersburg included the following steps:

1. Analysis of modern technical solutions;
2. Conducting of RF surveys;
3. Development of technical specifications;
4. Analyzing the companies that are capable of realization of Technical Specification;
5. Cost analysis of the solutions;
6. Holding competitive procedures for the project realization;
7. Direct implementation of the project;
8. Testing and training of the employees;
9. Commissioning;
10. Analysis of the efficiency of use.
3. Results

The project implementation plan was formulated in January 2018. The main difficulty was the need to cover and provide reliable Wi-Fi coverage in ten buildings of RANEPA in St. Petersburg with the required bandwidth, scalability, flexible centralized management and security policy settings.

On the basis of the analysis of wireless Wi-Fi technology capabilities, as well as of the tasks that are resolved within RANEPA, Saint-Petersburg, the requirements for the projected network were formulated, which formed the basis of technical specifications.

One of the first stages of the project was implementation of radio frequency modeling and subsequent survey. This was necessary in order to accurately determine the required number of access points, as well as their installation locations.

Specialized software was used for the simulation. Using the construction plans of the buildings, a preliminary scheme for the placement of access points was prepared, and a map of the projected radio coverage zones was built.

The results were taken as the initial ones during the radio survey. The data obtained at the modeling stage were compared with the results of full-scale tests in the buildings of RANEPA in St. Petersburg, which allowed to take into account the features of the layouts and radio transparency of building materials that were not reflected in the drawings and were not taken into account in the models.

It took two weeks to make modelling and survey. As a result, the required number of access points (328) and the exact places of their installation were determined. These data become the source for the design of SCS.

When working on the issue of equipping RANEPA facilities in St. Petersburg with a Wi-Fi system, special attention was paid to the principles of user authorization, the need for which is determined by the current Russian legislation. Authorization can be carried out on the basis of its own authorization center, combined with AD (active directory – means of user authorization to enter the computer and computer network of the Institute) or using external authorization services. The peculiarity of external authorization is the relative simplicity and low cost at the construction stage. RANEPA in St. Petersburg has to pay monthly for equipment, data channels and an external controller, as well as additional communication channels to all the buildings of the Institute, which will lead to a significant increase in the cost of the project. The use of internal authorization requires higher financial costs at the initial stage of the project, which are associated with the purchase of equipment, but later the cost of ownership of the system becomes lower compared to the previous option. Having considered these two methods, we can draw the following conclusions. Third-party authorization has a relative advantage – it is simple and has low cost at the construction stage. Authorization is carried out on the external service by the user's phone number. At the same time, since RANEPA in St. Petersburg does not have access to databases of operators, then we do not know who uses our network, therefore, the network will be able to use all the residents of nearby houses and all passers-by. It should also be noted that it is a possibility of our network unauthorized users or intruder. Besides:

1. The use of remote authorization does not enable integration of a Wi-Fi network with a network of RANEPA, Saint-Petersburg and provision of the access to resources (electronic databases, subscription resources, online broadcasts of presentations, resources, network, studbox (online resources for teachers and students) as the users traffic comes through the remote controller, and uses communication channel outside the network of the Russian Academy in St. Petersburg.

2. There is no way to rank users by resource access levels.

3. The third-party operator has full control over the user traffic, which can lead to leakage of passwords and user logins, and their personal data.

4. The mechanisms of storage and transfer of user credentials are not clear, logins and passwords from AD can be accessed by a third-party company.

5. There may be a slight delay in functioning of the network.

6. RANEPA in St. Petersburg incurs fixed costs and pays monthly for equipment, data channels for Wi-Fi and an external controller.
7. Additional channels will need to be provided to all RANEPA buildings in St. Petersburg, which will lead to a significant increase in the cost of the project.

   The use of internal authorization, based on own server, integrated with the AD will allow:
   1. Flexible management of the entire Wi-Fi system, by its integrating with LAN RANEPA, Saint-Petersburg.
   2. Provide full control over the actions of users and transmitted data on the Wi-Fi network, which will protect users and RANEPA in St. Petersburg from data leakage, as well as content filtering (blocking terrorist, pornographic sites, as well as torrents).
   3. Configuration and changes are carried out by the staff technicians and can be changed to meet the requirements of RANEPA in St. Petersburg.
   4. There is the possibility of ranking users according to access levels to the network of the Russian Academy in St. Petersburg.
   5. To ensure easy authorization setting, including future students and guests of the RANEPA, Saint-Petersburg using a single login and password both to log on to a PC and to Wi-Fi network, EIOS and other information services.
   6. There is no need for additional channels in each building, because the existing ones can be used.
   7. It is possible to use stationary PCs with Wi-Fi adapters in those places where there is no wired network or its resources are limited.

   Based on the above, at a high initial cost of creating an internal authorization service, its use in the future will make it possible to use the Wi-Fi network as an element of a single corporate network, where users, using their own mobile devices, can have the same capabilities as if permanently connected to the network workers. The analysis of the tasks solved with the help of Wi-Fi network, as well as the forecast of the network traffic volume and the number of users, allowed to formulate the following technical requirements for the development of the Wi-Fi network project in RANEPA in St. Petersburg:

   1. Access points must support 2.4 GHz and 5GHz frequencies. G/n/ac standards, and starting from 2*2 Mimo, POE. Bandwidth at a frequency of 2.4 GHz 300Mbps/s, frequency of 5 GHz starting from 867 Mbps. The use of two frequencies will allow to distribute the load in the network, giving modern devices greater bandwidth.
   2. Support of 120-150 devices per the point. On average, one point covers part of the corridor and 3-4 classrooms with a capacity of up to 30 people.
   3. The presence of a centralized controller for the network management.
   4. Construction of a centralized control system of Wi-Fi points and switches with the capability of automation of the firmware updating process of Wi-Fi points and switches, centralized backup and recovery of configuration files, logging changes in configuration files on devices.
   5. Implementation of multi-level authorization model with different levels of access to internal resources, authorization in AD. Ability to print temporary passwords with different expiration dates.
   6. Statistics: types of the most popular applications among the users, type g/n/ac and radio channel.
   7. Option of changing the authorization portal interface (branding) both by the customer and external companies (without access to the portal system), the use of third-party scripts for registration of guest users.
   8. Seamless roaming when users move from point to point without disconnecting voice calls.
   9. Option of connection to the management system of the existing Wi-Fi network based on Cisco.
   10. Active system of suppression of hostile users and access points or networks with the same name.
   11. Operation of the controller and management system as a virtual machine based on cluster hyper-v 2016.
   12. Possibility to overlay the map of buildings and allocation of the points on it.
   13. Tracking option of the Wi-Fi network users movement between the points and the history of transit.
   14. Option of analyzing of the transmitted packages through wireshark to diagnose the problems with the users activities.
15. Technical support should be provided daily and 24/7. Replacement of the equipment after RMA confirmation should be carried out NBD (next business day).

4. Discussion
After formulation of technical requirements, capabilities of various companies for the project implementation were considered.

Analysis of the commercial proposals received from several companies showed that the cost of building a Wi-Fi network core with the internal authorization can be comparable with the proposals for external authorization and ranges from 2 000 000 to 2 500 000 Rubles, and starting from the second year of the system ownership will allow the Russian Academy in St. Petersburg to save about 1 000 000 Rubles per year for one building (table 1). When scaling the network to other RANEPA buildings in St. Petersburg, it will be necessary to purchase only access points and switches, and the use of LAN channels will create a single seamless Wi-Fi network. «Extreme» stands for cost of ownership per year at 1$=58 Rub is 1 458 352,00 Rub. while Aruba suggesting the contract for 3 years - cost of ownership would be 1 175 660 Rub. (525 220 Rub. per year).

Table 1. Capabilities of various companies for the project implementation.

| Seq. No | Company No | Vendor   | Compliance with Specification | Cost Total       | Cost Ownership |
|---------|------------|----------|-------------------------------|-----------------|----------------|
| 1.      | Company 1  | Extreme  | Corresponds                   | 16 763 409,09   | 25,144$        |
| 2.      | Company 2  | Cisco    | Corresponds                   | 18 550 537,00   |                |
| 3.      | Company 3  | Aruba    | Corresponds                   | 15 081 842,54   | 787 830,00     |
| 4.      | Company 4  | Cisco    | Corresponds                   | No data is provided |                |
| 5.      | Company 5  | Eltex    | Does not correspond           |                 |                |

HPE (Aruba) is one of the top three market leaders in wireless solutions, that can be proved by Magic Gartner Magic Quadrant 2018 [20] (Figure 1).

Figure 1. Market leaders in wireless solutions proved by Magic Gartner Magic Quadrant 2018.
And also has the highest score for products and services for wireless networks (Figure 2) [21].
Figure 2. Score for products and services for wireless networks.

Thus, the analysis of technical solutions showed that the systems built on the equipment of Cisco or Aruba will have the greatest efficiency. The technical specification was put up for a competitive auction, with a number of participant companies. The winner of the auction was the company Complete, which presented the technical solution based on Aruba. After completion of the planning and preparation phase, installation of access points and SCS components was initiated.

This was followed by installation of Ethernet switches (17 units) in all buildings, connecting access points to them, integration with LAN and routing configuration. In parallel, at the existing Microsoft Hyper-V cluster, virtual machines for the Aruba Wi-Fi controller, Aruba ClearPass policy management servers and Aruba AirWave monitoring and management systems were deployed. After the completion of the infrastructure preparation works, the Wi-Fi network setup began. First, the Aruba Wi-Fi controller was configured, which allowed to provide basic services such as centralized access point management, tools for creating wireless networks, and dynamic power and channel management (ARM) functionality. This was followed by the most difficult and laborious stage of the project – work on setting up the Aruba ClearPass policy management server. It was integrated with the extensive infrastructure of Microsoft Active Directory RANEPA in St. Petersburg and Wi-Fi controller Aruba, network access policies were formed based on the attributes of user accounts and computers, tools for management of the process of creating guest accounts were configured. The next step was to integrate with the existing Wi-Fi network built on Cisco equipment. This ensured the application of uniform access policies for all Wi-Fi users, regardless of which educational building they are located and to the Wi-Fi network of which manufacturer they are connected.

The final part of the Aruba ClearPass setup was its integration with the Fortinet firewall cluster deployed at RANEPA in St. Petersburg. This integration allows to automatically apply on the firewall the access policies assigned to the users at the stage of authentication and authorization in the Wi-Fi network. In the process of Aruba ClearPass configuring, testing and debugging were performed at each step. The final stage of the project was the setup of the Aruba AirWave monitoring and control system. According to its results, RANEPA in St. Petersburg received a single interface for monitoring wired and wireless equipment (including Cisco), configuration management and storage of logs.
The project was implemented within two months, as a result of which RANEPA in St. Petersburg received an effective wireless Wi-Fi system. Currently, the network operates steadily, meets all the requirements, has more than 10,000 users, of which 3500-4500 are active daily.

Construction of a Wi-Fi network required installation of more than 300 access points and 14 commutators. Such a large infrastructure requires a lot of time to configure this network, which can lead to errors in the settings and information security gaps. In this situation, a unified management and monitoring system was needed, which simplifies the network configuration and its changes. It takes a few minutes to propagate the changes and update the firmware to such a large number of devices. Network administrators can in real-time monitor network problems, traffic volumes, number of users, configuration changes, and can revert to previous settings in case of problems.

AirWave shows potentially hostile points and devices (Figure 3).

![Figure 3. Potentially hostile points and devices.](image)

It also displays information about potential attacks on the wireless network and data about the devices used (Figure 4).
Figure 4. Potential attacks on the wireless network and data about the devices used. The system helps to configure flexible access rules and restrictions for each user (Figure 5).

Figure 5. Flexible access rules and restrictions for each user.
5. Conclusion
Thus, logistical development of innovative single information space consider building the single information space (SIS) on the basis of a universal software platform with a set of well-tested industrial software modules used, which made it possible to use not only its standard solutions, but also to refine and adapt them to the business processes existing in RANEPA in St. Petersburg, as well as to develop own systems with subsequent integration with existing solutions.

The analysis of the operation of the Wi-Fi network showed that it fully meets the needs and business processes of RANEPA in St. Petersburg.

The introduction of Wi-Fi network into commercial operation has allowed to bring the use of SIS to a new level for the students and teaching staff of RANEPA in St. Petersburg.

This is primarily due to the full coverage of all academic buildings and dormitories, a simple and understandable way of authorization, integration into a single digital space of RANEPA in St. Petersburg.

Of particular note is the level of comfort for international students.

RANEPA in St. Petersburg is developing, the new campuses and emerging facilities will be equipped with a Wi-Fi network Aruba, as a well-proven one.

Wi-Fi wireless network has become the core of communication for students, employees and guests of RANEPA in St. Petersburg, which allowed to bring the SIS to a new level.

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