CONTRIBUTION OF RENAM TO INFORMATIONAL SERVICES DEVELOPMENT FOR HIGHER EDUCATION AND RESEARCH

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Abstract

The transition of the traditional science and higher education to e-Science and e-Education is fueled by the ever increasing needs to have access, process and visualize of exceedingly large amounts of data that can't be managed without modern communication and computing instruments. In the past years the European Commission has funded, through a number of targeted initiatives, creation of specialized eInfrastructures for providing IT services to research and educational communities to support collaborative research and education. In Eastern Europe, including in Moldova the existing resources of eIfrastructures are less developed than in Western Europe (ANTUN BALAZ, et. al., 2011). Advancing the Information Society, strengthening of the local eInfrastructures, activating new user communities, enabling access to modern educational content and technologies, to new instruments for collaborative research, would strongly contribute to closing the existing gap, and thus bridging the digital divide, stimulating research and consequently alleviating the brain drain in the region. At present the main facilities like Research and Educational networking infrastructure for effective data exchange, access to large-scale computing and other e-Infrastructures services is rapidly increasing in Moldova. eInfrastructure designates a new generation of integrated ICT based infrastructures and is widely considered as a key enabler of research and education development.

Keywords: Research and educational networks, computing infrstructures, e-infrastructures and services

Introduction

The term e-Infrastructure refers to a combination and interworking of digitally-based technologies, resources, communications, and organizational structures needed to support modern, international leading collaborative research. Such infrastructures are oriented to support a distributed medium based on high-bandwidth networks, distributed computing Grid, HPC, scientific Cloud resources and respective data repositories. Nowadays e-Infrastructures provide researchers electronic resources accessible on a 24-hour basis, regardless of the place, and is a unique tool for the development of collaborating applications. Modern e-Infrastructures require tremendous data exchanges and respective communication bandwidth.

Eastern Europe countries including Moldova are developing national e-Infrastructure platforms consist of networking and computational (Grid, HPC, Cloud) facilities, electronic libraries, scientific data repositories, etc. Taking into account European models, National Research and Educational Network (NREN), National Grid Initiative (NGI) and HPC users' association have been established in Moldova, which are actively participating in the regional and pan-European projects, including initiatives focused on integration in pan-European e-Infrastructures. There are many qualified research teams intensively using computational and data resources provided at national and European levels.

The main aim of this article is to introduce the status of e-infrastructures in Moldova emphasizing on networking and available computational facilities, e-services and international collaboration. The overview of network infrastructures operated by the NREN RENAM and the computational and storage resources provided by the coordinated by NREN National Grid Initiative are introduced including its collaborations with the pan-European research and education network GÉANT (GÉANT pan-European research and education network, 2014), European and regional Grid, HPC and Cloud infrastructures (EU FP7 EGI-InSPIRE project, 2014). The key research applications and services are presented covering a wide range of scientific disciplines, such as particle physics, life sciences and computational chemistry, earth and climate sciences, economical behavior, computational engineering, etc.

1. Research and educational networking infrastructure and services

European Commission started deployment of common research and education Pan-European networking infrastructure with the aim to unite all research and educational institutions in Europe since 1993. At present research and educational networks are considering as basic element for other components of modern e-Infrastructures development.

In Moldova NREN RENAM (Research and Educational Networking Association of Moldova) was established in 1999. Main activities of RENAM are developing taking in account experience of other European NRENs and consist of:

- constant development of communication and informational infrastructure and modern high-capacity communication media;

- providing access to the national and foreign scientific databases and organizing access to scientific publications and educational informational content;
- National R&E network now is capable to interconnect all principal research, educational, medical and cultural institutions and to provide them with Internet access, e-Learning, e-Science, distributed and high performance computing and other services.
- Creation and development of basic infrastructure (nodes and highways) of Nation-wide scientific-educational networking backbone and providing a stable mutual access to national and foreign information resources;
- Elaboration and implementation of new eInfrastructure technologies, services and information resources in order to ensure a high level of educational processes, investigations and close interaction with the European and the world scientific and educational community.

The main functions and services that are supporting by NREN in Moldova summarized in the Fig. 1.

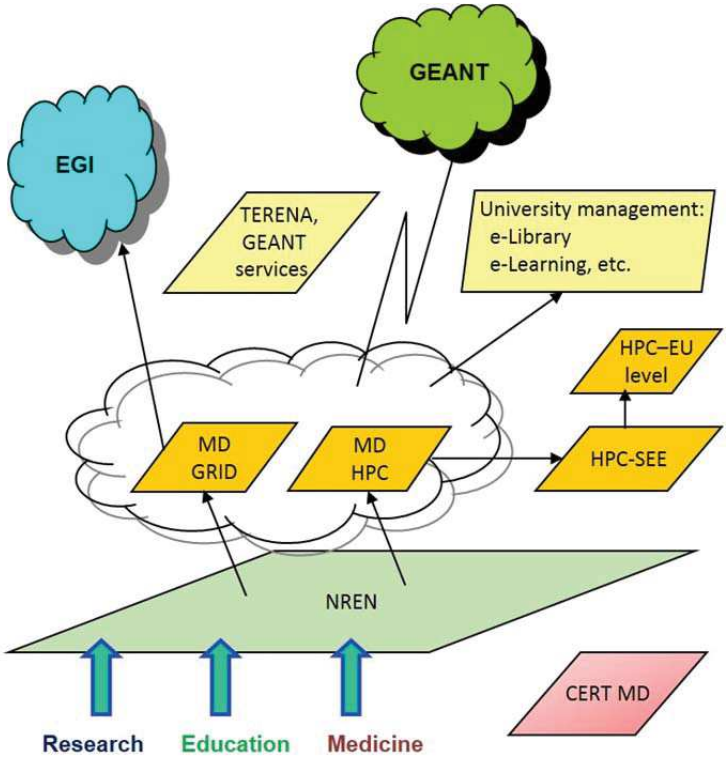

Figure 1. Operational structure and main services of NREN in Moldova.

For research and educational community in Moldova, networking infrastructure that also offering Internet access was established in 1998-2000 within several initiatives supported by a series of national and international projects. Now RENAM network consists of fiber-optic communication channels that uniting institutes of the Academy of Sciences of Moldova

(ASM), leading universities and other national scientific - educational institutions. For users from research and educational community implemented and developing a variety of technologies and services (AAI, mobility, access to computing resources, etc.) (BOSTAN I., et. al., 2014).

A modern network infrastructure is one of the basic components of e-Infrastructure that is supporting the requirements of e-Science and e-Education. For the network level it is crucial to possess high performance and scalable advanced infrastructure operated by NRENs for the sustainable development and implementation of new services. As a preferable solution from the initial stage of network design we considered optical fiber based networks that have a wide variety of network deployment approaches and technology choices. Such networks ensure the fixed cost of the use of the infrastructure and at the same time provide scalability up to Tbps, as the network grows.

Research, educational and medical institutions have supported the foundation in 2006-2007 of the National Grid Initiative, which was created with the aim to develop and maintains of the distributed scientific computing infrastructure for processing large amounts of data.

Mobility technologies, big data, virtualization and cloud computing is rapidly changing requirements for NREN infrastructure and utilized communication technologies. One of the most important conditions for building distributed information processing and high-performance computing systems is the presence of high-speed and reliable access channel to access networked resources. For this purpose at the national level is using RENAM network infrastructure, which unities informational resources of the ASM and leading universities in the integrated information processing complex with access to the Internet. RENAM network topology represents three-tier architecture. The first level is local networks of universities' campuses, organizations and institutions. The second level is the optical network for connection access nodes (points of presents, with bandwidth 1Gbps and more) that linking local networks of research institutes and universities to RENAM network backbone. The third level comprises the central communication node that provides access to the Trans - European Academic Network GEANT (see Fig. 2) via the main external fibre optics channel Chisinau - Iasi (with scalable bandwidth up to 3*10 Gbps). Creation and putting in operation in 2010 of the fibre optics channel for access to the GEANT network was realized in the framework of international projects SEE-GRID-SCI (funded by the European Commission) and NIG 982702 - New RENAM-RoEduNet gateway based on CWDM technologies implementation (funded by NATO).

European Commission supported some initiatives to investigate the status of NRENs from organizational and technical points of view in Eastern Europe and propose the appropriate approaches for their further development. In 2006 - 2007 NRENs from Eastern Europe region were involved in the EC project "Distributed Optical Gateway from Eastern Europe to GÉANT (Porta Optica Study - POS)" (Porta Optica Study project, 2008), which aimed at the analyzing of the most suitable approaches for realization of regional optical infrastructure that could be further integrated to Trans-European Academic network GÉANT. During the project realization a detailed study of possible solutions to build fiber

optic infrastructure for connecting R&E networks of the Eastern European countries to GÉANT network was performed. In the project were developed recommendations build a number of cross border connections that will unite neighbor NRENs, determined principal ways to organize connection of elaborated regional infrastructure to GÉANT via Points of Presence in several countries. In 2011-2013 a new feasible study of research e-Infrastructures development in the Eastern Europe countries was performed in the framework of CEENGINE project (EU FP7 CEENGINE project, 2012).

In both projects formulated utilization of "Dark Fibre" (DF) paradigm was suggested as the most appropriate solution for NRENs optical infrastructures implementation. This concept should be well understood in order to properly evaluate the economic aspects of such infrastructure development. Fibre acquisition and operations involve new cost categories that have to be recognized and added to the economic model of operations of fibre based NRENs. In addition, the economical assessment should be done for long term – DF is usually a long-term acquisition and should be evaluated as such. NRENs DF interconnections, so called Cross Border dark Fibre – CBF concept, is now widely used by European NRENs for optimization of GÉANT optical backbone construction.

Figure 2. RENAM network - current state of national and international connectivity.

One of the successful examples of the elaborated CBF connections realization was the project of DF link implementation between NRENs of Romania and Moldova. Integration of NREN of Moldova to the regional Research & Educational networking infrastructure has begun in 2001 when cooperation with Romanian NREN RoEduNet was established and the first joint project "RENAM-RoEduNet networks direct link and gateway construction" was elaborated and submitted to NATO Networking Grants Programme. The project was successfully realized in 2003 and since this time access to GEANT resources for Moldovan NREN users is carrying out through Romanian NREN. Basic conditions of external connectivity development for NREN of Moldova through RoEduNet are determined by the following principal documents:

- RENAM–RoEduNet Agreement that determines the policy of direct RENAM – RoEduNet connection utilization and stipulates parameters of RENAM access to GEANT infrastructure. The first release of the Agreement that had been signed in 2002 was based on available connection parameters offered by radio-relay technology; the Agreement was renewed in 2006 and in the second version were reflected perspectives of the optical connection construction and utilization;
- The adopted list and specification of external routes elaborated during EC "Porta Optica Study" project (contract number 026617) realization (Porta Optica Study project, 2008).

In 2007 RENAM and RoEduNet jointly submitted application to DANTE (Delivery of Advanced Network Technology to Europe, located in United Kingdom) - GEANT network operator. This document indicated the parameters of the RENAM network traffic capacity that can access GEANT network through RoEduNet.

RENAM and RoEduNet elaborated argumentation and technical solution of fiber optic communication link creation for support of regional scientific and education cooperation and providing access to GEANT network for research and educational communities of Moldova. The funding of the link practical realization was supported within European Commission SEE-GRID-SCI project and necessary funding of the optical communication equipment procurement was provided by NATO Committee on Science for Peace and Security joint project entitled "New RENAM-RoEduNet gateway based on xWDM technologies". The DWDM based solution was implemented for permanent operation of the created optical link.

RENAM together with other NRENs from countries included in the Eastern Partnership Programme (EaP) initiated in 2012 dialogue with EU experts having the aim to investigate possible solutions for integrating EaP region to GÉANT and support of potential project elaboration focused on regional research and education network creation. An examination performed by the expert team from GEANT focused on determining the resilient and cost effective technical solutions for deploying regional optical network infrastructure that would unite all EaP countries. Special attention devoted to finding solutions of effective integration of EaP networking infrastructure to GÉANT. The various approaches of the EaP regional network infrastructure development and its integration to GÉANT were discussed. Fig. 3

presents schematic view of the whole regional network architecture proposed in the Concept Note of the new regional E@P.connect project.

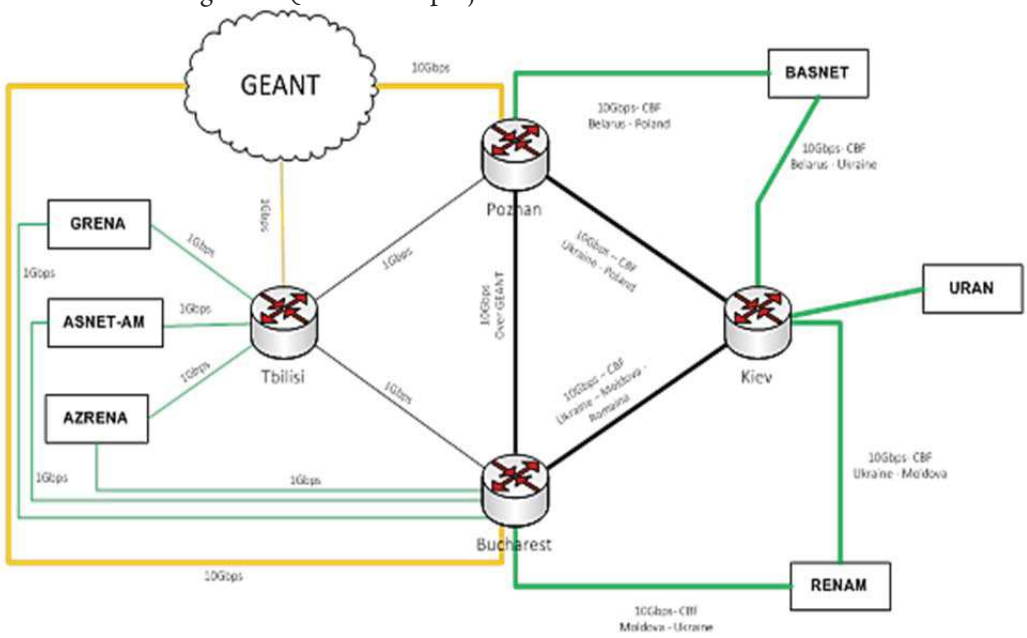

Figure 3. Schematic view of the regional network architecture.

2. Computing infrastructure and services

Modern Scientific Computing infrastructure is based on using parallel architectures specialized on running complex applications and integrates the following components:

- HPC - Clusters' systems;
- HPC - Supercomputers;
- Distributed computing infrastructures – Grid and Scientific Clouds;
- Libraries and software packages for parallel algorithms design and programming
- Instruments for complex applications development and porting.

Historically in Moldova, the first scientific computing resources had begun developing from the initial deployment in 2006 of the first Grid cluster that was integrated in the regional South-Europe Grid infrastructure. Since this time Moldova is actively involved in regional and European programs for cooperation in the field of scientific computing (PETRU BOGATENCOV & GRIGORE SECRIERU, 2012). European institutions are paying significant attention to new initiatives for the development of high-performance computing infrastructures, resources and technologies to support development and execution of complex parallel applications. In recent years, several initiatives have been launched, aimed at creating of supercomputer centers and their integration into a common European HPC infrastructure. Taking in account the significant investments in creating of high-performance computing

infrastructures in Europe, currently main attention is focused on designing and implementation of instrumental support for rising effectiveness of unique computing systems use. Coordination of activities in this area is carried out within the European initiatives like PRACE project (Partnership for advance computing in Europe) that having the aim to create a unique HPC ecosystem. This ecosystem has to bring together providers of computing resources and diverse users' communities - from research, educational institutions, specialized software companies as well as from small, medium and large enterprises - consumers of computational experiments results. HPC ecosystem includes several levels of HPC installations depending on their performance and mod of utilization. On the top, "zero" level (Tier-0) are located supercomputing resources of the world leading supercomputer centers. HPC facilities available in Moldova taking in account it real capacity at present are corresponding to Tier-2 level representing HPC centers of research institutes and universities.

Important for Moldova was participation in the regional project HP-SEE (High-Performance Computing Infrastructure for South East Europe's Research Communities) that allowed for local research and educational institutions to get access to regional HPC resources. Regional HPC infrastructure combines powerful HPC clusters and various supercomputers provided by the project participants from five countries involved in the project: Greece, Bulgaria, Romania, Hungary and Serbia. Regional HPC infrastructure is heterogeneous - includes supercomputers and clusters based on Intel/AMD CPU and GPU. HPC resources that are offering to users' community included also two supercomputers IBM Blue Gene/P installed in the Bulgarian Supercomputing Center of the Agency "Electronic Communication Networks and Information Systems" and in the Western University of Timisoara (Romania).

During HP-SEE project realization in Moldova have been identified and proposed for implementation several technologies and tools for offering access to advanced computing resources and services that developing in the South-East Europe for researchers from Moldova. Members of the project from Moldova participated in a series of specialized trainings organized within HP-SEE, LinkSCEEM-2 and PRACE projects. For providing access for developers and users of complex applications from scientific and educational institutions of Moldova in the framework of HP-SEE project in 2012 was signed the Cooperation Agreement between RENAM and computer centers in South-Eastern Europe. The Agreement determines conditions of providing access to the regional high performance computing resources that comprises more than ten high performance systems.

HP-SEE project achieved its aim to strengthen scientific cooperation and to promote activities in the field of high performance computing. As a result, it contributed to regional development and involvement of Moldova into the European HPC resources development trends.

In May 2010, the Academy of Sciences of Moldova and RENAM Association had signed a Memorandum of Cooperation with the Joint Institute for Nuclear Research (Dubna, Russia), which related to cooperation in the field of joint development and use of HPC and

distributed computing infrastructures. In the Memorandum determined wide spectrum of joint activities including elaboration and preparation for execution of complex applications that can be launched for running on remote high performance computing resources. This Memorandum strengthened cooperation between researchers from different countries and created conditions for solving complex problems without the need for scientists to travel to resource centers for getting access to computational resources and perform the necessary calculations.

Support of international projects allowed to begin forming national high-performance computing resources in Moldova. In the State University of Moldova was installed high-performance computing cluster with parallel architecture. Multiprocessor clusters were deployed in the Institute of Mathematics and Computer Science of ASM and in RENAM Association.

Distributed computing infrastructures and service are very important component of the modern scientific-educational eInfrastructures. Historically the first distributed computing infrastructure deployed in Moldova was Grid computing infrastructure - a specific e-Infrastructure element, which provides remote access to distributed computing power. Grid infrastructure is able to offer:

- Joint use of computing resources
- Access to distributed data storage resources
- Shared access to large experimental facilities and remotely controlled experiments
- Creating a distributed experimental facilities and resources
- Automatic retrieval of data and resources in the network
- Promoting cooperation and joint implementation of projects.

In 2013 in Moldova began activities dealt with deployment of the scientific cloud infrastructure. Development of scientific clouds is rather new, but perspective direction of computational technologies development. For SEE region needs in cloud technologies deployment were analyzed during execution of SEERA-EI project funded by European Commission ERA-NET Programme. The analysis produced had shown strong interest of the regional research communities in use of scientific clouds computing resources. As a resulting outcome of SEERA-EI project was recommendation to launch regional Pilot Call for projects in the area of scientific cloud computing.

Another important initiative for Moldova that combines analysis of optimal solutions and practical deployment of regional scientific cloud infrastructure is the regional project "Experimental Deployment of an Integrated Grid and Cloud Enabled Environment in BSEC Countries on the Base of g-Eclipse (BSEC gEclipseGrid)" supported by Black Sea Economic Cooperation Programme (http://www.blacksea-cloud.net). The aim of this project was to select middleware for implementation of computing architecture that provide a collaborative, network-based model that enables the sharing of computing resources: data, applications, storage and computing cycles. Special outcome of the project was introducing a federated Cloud infrastructure, which can provide different solutions for universities, scientific and research communities and more.

Next stage of distributed computing infrastructure development is focused on realization of the perspective approach of combining the Grid and Cloud resources together as a single

enhanced computational power and offer the possibility to use Grid or Cloud resources on demand. As an example, if the user requires parallel computational resources, he will submit a job on the Grid, but if the user needs any specific software or environment to solve some special problem, access to distributed data repositories, he can use a dedicated Cloud service or virtual image for this purpose. This united platform will make possible to solve the following problems:

- increasing the effective usage of computational resources;
- providing additional different services for scientific and research communities;
- close collaboration between different countries to solve common problems.

The general scheme showing the evolution of the integrated computational infrastructure in Moldova presented in fig. 4.

As perspective development of cloud services we considering further development of the cloud infrastructure with implication computational resources of the all institutions connected to NREN. This will allow to select and unify basic services, effectively realize and deliver them to all interested research and educational institutions. As basis services that have to be unified and adapted to use in common cloud infrastructure we considering electronic libraries catalogues, e-libraries access, universities management systems, learning management systems (like Moodle, Sakai, etc.), information system for national research projects support. The mentioned list of unified services is opened for development and new services can be implemented and provided by using cloud resources. To simplify and unify the access to all services offered by common computing infrastructure will be used federated principles – instruments of the National Identity Federation can ensure users' authentication and authorization procedures.

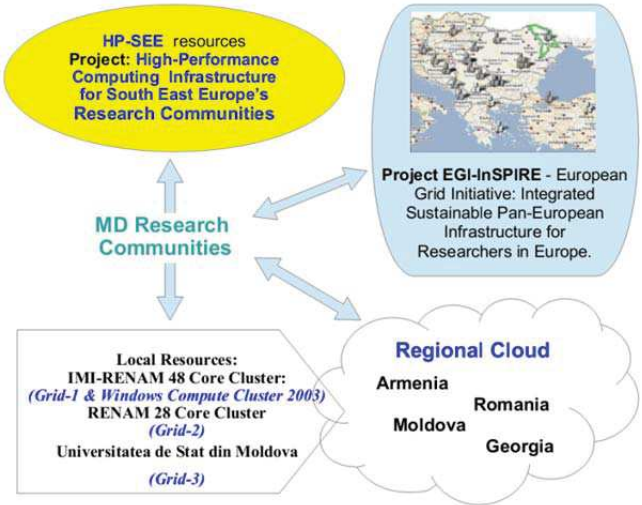

Figure 4: The evolution of the HPC, Grid and cloud infrastructures in Moldova

For management of computing infrastructures at the national level in each European country had been set up organizational structures liked National Grid Initiatives (NGI). MD-

Grid - National Grid Initiative of Moldova was officially inaugurated on the plenary session "National Grid Initiative MD-Grid: presentation and inauguration" of RENAM Users Conference – 2007 on May, 14 2007 after receiving approval letters from Ministry of Information Development of Moldova and the Academy of Sciences of Moldova (http://www.grid.md). To create MD-GRID NGI used organizational model of the Joint Research Consortium (JRU) develop and recommend at the European level. The MD-Grid NGI Consortium governed by RENAM as the coordinating body joins 10 research, education and industry institutions that expressed their intent to participate in the processes of National computing infrastructure building and using. Several new scientific and educational institutions have expressed interest in the future to join the MD-GRID NGI.

The main activity directions of the created in Moldova National Grid Initiative are summarized as followed:

- MD-Grid NGI participates in strategic European Programs for the development of eInfrastructures. The operation of the MD-Grid NGI implements the general EU policy on the development of national initiatives for the coordination of actions related to eInfrastructures and especially to scientific computing infrastructures.
- Integration of scientific computing actions (infrastructures, middleware and applications) with the broadband network into a standard e-Infrastructures system. The optimization of exploitation of advanced network resources and services, which can serve the new e-Science generation and will attract the greater users' community of the information society to the mass adoption of advanced e-Infrastructure services.
- The permanent development and administration of the National computing infrastructure.
- The organization access for national users' communities to the regional and European computational resources (HPC, Grid, scientific clouds, etc.).
- The educational and training events organization; the technological support of national users' communities.

MD-GRID NGI operates the National Center for issuing digital certificates – Certification Authority (CA), which serves as a local CA and process registration requests for the issuance of certificates for Moldovan scientific and educational institutions (VALENTIN POCOTILENCO, et. al., 2009). MD-Grid CA operates under the auspices of the European Certification Center EUGrid-PMA and uses its rules and procedures for issuing digital certificates (EUGridPMA - Building Trust for Distributed IT Infrastructures for Research, 2014). Taking into account the importance of national infrastructure for authentication and access authorization (AAI), to ensure the provision of safe access to national and international computing and information resources, the existing Certification Authority is preparing procedures for issuing new certificates, which must meet the requirements of the research and educational organizations of Moldova in deployment of users' identity management systems.

3. Support of training and rising awareness of e-infrastructures users

User support and training is an important issue for the success of the implementation of parallel and distributed computing technologies. Organization of trainings for the developers of parallel applications in remote mode (online) is a relatively new approach for Moldova. To achieve this goal was produced the analysis of various open source Learning management systems, which can be used for development and use of the interactive tutorials in on-line mode. Were analyzed software packages and systems that implementing the following remote training and learning technologies:

- human networking support and distance learning;
- on-line interaction between research groups (for closed groups);
- Systems of Web-conferencing.

As a platform for Web-conferencing was selected and deployed Big Blue Button (BBB) tool, which allows integrating third-party applications, in particular networking tools and distance learning systems. After studying the variety of distance learning packages, the interest was focused on Sakai and Moodle Learning Management Systems. For organization of computing infrastructure users' trainings in the State University of Moldova and in the Institute of Mathematics and Computer Science of ASM were installed two selected open source software packages: Sakai and BigBlueButton. Integrated software toolkit allowed to organize the environment for research groups' communication. Trainers received comprehensive tool to prepare educational curricula, to support the interactive multimedia learning process and means for on-line delivery of learning content.

Another important element that enhancing eInfrastructures users' literacy is organization of certificated education. NREN of Moldova together with universities – members of the Association is actively involved in promoting of specialized IT trainings and certified education. At present to eInfrastructures users' communities available and fruitfully developing certificate education organized by CISCO Academy and Microsoft Academy training programmes. Established contacts and started negotiations of certificate training organization in Moldova with Oracle University and Juniper Networks Certification Program.

Conclusions

The rapid development of information technologies directly contributes to the development of research and educational processes. New technologies significantly influence to the quality of specialist preparation and their adaptation to real working environment. This paper is summarizing experience of propagation of new information technologies and their wide utilization by creation and development of basic networking and computing infrastructures in Moldova.

Participation of NREN in e-Infrastructure components development and operational support is very important for keeping their services portfolio updated and attractive for users' community. From other side these activities influence on modernization of basic networking

infrastructure, requiring redesigning of the network and implementation of new architectural solutions. NREN is staying in touch with community need when follows modern trends in new e-Infrastructure components and services realization.

In many cases, implementation of distributed e-Infrastructures requires international cooperation that includes efforts of many NRENs for uniting resource's providers from different countries and creation dedicated networking segments for complex e-Infrastructure components operation. This is why development of modern e-Infrastructures is considering as motion power for basic networking infrastructure and international connectivity development.

For organization of e-Infrastructure components operation at national level, it is important to create clear rules and organize cooperation of various teams responsible for networking and computational components maintenance and development. We consider that NREN personnel have to be engaged in preparation of users' community to utilize effectively new services and resources. For achieving its goals this activity requires close interrelation with connected research and educational institutions, computational resources providers, finding experiences teams and persons that can and ready to share their skills with other community members, prepare own specialists employed in NREN that can support and train end users. That will allow overcoming existing barriers – sometimes users not ready to use eInfrastructure services and possible opportunities because considering it rather complicated and requiring extreme efforts from them. Only realization of the whole set of measures for making access to eInfrastructure resources more easier will allow to make new e-Infrastructure services more attractive.

Another promising direction of services development is using of Cloud resources that are creating as a part of the national, regional and in perspective - European Cloud computing infrastructure. National scientific Cloud infrastructure can interact with National Cloud infrastructure for e-governmental services that developing in Moldova in the framework of the M-Cloud project. This will allow offering additional computing resources for demanded and convenient IT services deployment at the national level.

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