e-Infrastructures for Research and Education in Eastern Europe Partnership Countries

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ABSTRACT

In the paper the current status of research and educational e-Infrastructures in the countries included in European Eastern Partnership Programme (EaP) is briefly presented. Taking into account the needs of research communities, solutions for the development of regional networking infrastructure based on cross-border connections (CBF) implementation are proposed. The main goal is to deploy a high performance, reliable and cost-effective networking backbone uniting scientific – education e-Infrastructures of EaP countries and providing interconnection to the Trans-European academic network GÉANT [1].

Keywords

Computer science, optical networks, regional connectivity, Grid, Cloud, HPC infrastructures.

1. INTRODUCTION

Term e-Infrastructure refers to a combination and interworking of digitally-based technology (hardware and software), resources (data, services, digital libraries), communications (protocols, access rights and networks), and the people and organizational structures needed to support modern, internationally leading collaborative research [2]. Such infrastructures are oriented to support a distributed medium based on broadband communications, distributed Grid, HPC and scientific Cloud resources and respective data repositories. All these facilities are forming a new research environment enabling shared access to unique or distributed scientific facilities (including data, instruments, computing and communications). e-Infrastructures developing worldwide provides researchers and economy a common market of electronic resources, accessible on a 24-hour basis, regardless of the place, and a unique tool for the development of collaborating applications. e-Infrastructures combine various e-science tools that include sensors and sensor networks, databases, data mining, machine learning, data visualization, and computing resources at enormous scale. Modern e-Infrastructures require tremendous data exchange and respective communication bandwidth. Hence, developed research and education network infrastructure is vitally important. The paper describes solutions for regional optical backbone implementation that are devoted to the creation of high performance, reliable and cost-effective connections between national scientific – education networks in the region of Eastern Europe countries. Available and suggested backbone connections are used for integration of regional research and education user communities to Trans-European academic infrastructure GÉANT. Realization of new optical cross-border connectivities will ensure integration of EaP NRENs to the common Trans-European informational infrastructure and will improve access to the

wide range of services available for the European research community.

2. REGIONAL USERS' COMMUNITIES AND AVAILABLE e-INFRASTRUCTURE RESOURCES

All Eastern Partnership countries are developing national e-Infrastructure components like Grid [3] and Cloud computing facilities, access to HPC resources, electronic libraries, scientific data repositories, etc. Taking into account European models, in EaP countries organizational structures for support of modern collaborative research - NRENs, National Grid Initiatives and HPC users' associations were established. They are actively participating in the regional and pan-European projects, including initiatives focused on integration in European e-Infrastructures. In the region there are many qualified research teams intensively using computational and informational resources provided at national and European levels.

The e-Infrastructure **in Armenia** mainly uses the facilities of ASNET-AM (Academic Scientific Network of Armenia) National Research and Educational network, which currently connects more than 60 end sites through 39 Point of Presences, including the Ministry of Education and Science, Ministry of Emergency Situations, the State Committee of Science, and the National Statistical Service. The computational resources (about 500 cores) are concentrated in seven sites among the leading research and education organizations of Armenia located in Yerevan and Ashtarak. The infrastructure supports international virtual organizations operating in the high energy physics (ATLAS, ALICE) and environmental (EnviroGRIDS) fields. The main research teams using distributed computing and storage resources are in particle physics, life sciences and computational chemistry, earth and climate, astronomy and cosmology, computational engineering and other scientific disciplines. Armenia successfully collaborates with the pan-European and regional counterparts in different layers including:

- In the networking layer, ASNET-AM is a member of TERENA (Trans-European Research and Education Networking Association), RIPE Network Coordinating Centre, CEENet (Central and Eastern European Networking Association).
- In the infrastructural layer there is a strong collaboration within European Commission HP-SEE, EGI-InSPIRE and GN3plus projects and also, within g-Eclipse project funded by the Organization of the Black Sea Economic Cooperation.

The e-Infrastructure **in Azerbaijan** is arranged mostly by the Azerbaijan Research and Educational Network Association (AzRENA). AzRENA network connects 15 education and research centers. At present about 900 workstations serving 6000 users are connected to AzRENA network. Technology of AzRENA networking infrastructure is flexible that allows fast developing of regional education and academic networks and their integrating in a general network in the cities and regions of Azerbaijan.

There are other organizations providing access for education and research institutions in Azerbaijan, which AzRENA closely co-operates with. The Azerbaijan Networking Educational Technologies Project (AzNET) is a joint initiative of the Ministry of Communications & Information Technologies, Ministry of Education and Relief International. The AzNET continues network development efforts started by National Information & Communication Technology Project, the AzRENA's ICT initiatives, and the Information Program of the OSI-AF. The AzNET network has presence in Baku city and in the major cities and regions of Azerbaijan. The network is implemented as a fiber backbone with Points of Presence collocated in Public Switched Telephone Networks nodes. The backbone is based on Gigabit Ethernet technology.

Currently Azerbaijan has one high performance cluster. Custer has been deployed at the Laboratory of High Energy Physics of the National Academy of Sciences. The technical characteristics of the cluster are the following: the total number of cores is 850 with peak performance – 8,5T flops.and the storage capacity is 120 TB. The main applications using established infrastructure are in the field of high energy physics.

The national e-infrustructure for research and education **in Belarus** is arranged of key components in computer networking, Grid and HPC spheres. One of the main organizations engaged in the development of the Belarusian e-infrustructure is the United Institute of Informatics Problems of the National Academy of Sciences of Belarus (UIIP NASB). UIIP NASB is the leading institution for carrying out fundamental and applied research in the fields of information processing and networking technologies, computer science, applied mathematics, computer-aided design and other relevant fields.

The Belarusian NREN is based on the computer network of NASB - BASNET. Since 2007 BASNET is administrated by UIIP NASB. Today BASNET operates 20 basic network nodes, 10 Gbps core network, 90 km of fiber-optic channels and 1 Gbps connection to the Pan-European GÉANT network through the Polish NREN PIONIER. BASNET provides connectivity to 110 corporate users, among which there are research institutions of NASB, universities, republican and regional libraries, a number of government organizations such as the State Committee of Science and Technologies, Ministry of Agriculture, Ministry of Industry, State Committee of Chernobyl, Ministry of Health, Fund of Fundamental Research.

UIIP NASB is a coordinator of the National Grid Initiative (NGI_BY). Main participants of NGI_BY are the research institute "National Research and Training Center of High Energy and Particles Physics" of the Belarusian State University, the state institute "Joint Institute for Power and Nuclear Research - SOSNY" and UIIP NASB.

Stages of development of the Belarusian Grid infrastructure are the following:

- Connection of sites of organizations to the BASNET-GRID based infrastructure;
- Establishment of certification authorities (CA) of organizations;
- Establishment of Grid resource centers;
- Liaising with the industry within HPC resources consumers' association;
- Launching the state program of development of Grid resource centers of the National Grid network.

Applications areas include remote sensing of Earth system, modeling of Belarusian industries, image processing and automated diagnostic screening for Belarusian medical and research institutions - a number of distributed telemedicine systems deployed in Belarusian regions and in Minsk. Belarusian remote sensing of Earth uses BASNET infrastructure for exchange of space information received from satellites, serving the interests of agriculture, forest and water resources ecology research, etc.

HPC resources to the Grid community of Belarus are provided by the Multi-access Supercomputer Center, the subdivision of UIIP NASB. UIIP participated in three Russian-Belarusian supercomputer programs: SKIF (2000-2004); TRIADA (2005-2008) and SKIF-Grid (2007-2010).

The most important result of the SKIF programs is creating of the National Supercomputer and Grid Centers.

The main provider of the e-Infrastructure in **Georgia** is Georgian Research and Educational Networking Association –GRENA, which connects 32 institutions (71 physical connections). The backbone capacity is 1 Gbps and international connectivity is 200 Mbps provided by the local connectivity provider. The main networking services provided by GRENA are the following:

- Managed and guaranteed bandwidth;
- Virtual Private Network;
- Network traffic monitoring and analyses;
- Intrusion detection and prevention systems;
- Computer Emergency Response Team – CERT-GE.

In 2009 GRENA established the first Grid facility in Georgia, which is incorporated in the European Grid Infrastructure. The computational recourse of this site is 40 cores and storage element is 2 TB.

Several scientific applications from Georgia are using e-Infrastructure, among them are:

- Meteorology: Investigation of Advanced Research WRF (ARW) modeling system for weather research and forecasting;
- Plasma Physics: Study of acceleration of charged particles in relativistic plasma heated by ultra-intense pulses of laser beam;
- High Energy Physics: Collaboration with the CERN LHC ATLAS experiment;
- Life science: Quantitative description and modeling of the biochemical processes (e.g. point mutation process in DNA).

In **Moldova** RENAM Association is operator of NREN networking infrastructure and coordinator of operation and development of the basic e-Infrastructure components, such as HPC, Scientific Grids and Clouds. RENAM integrates resources of national e-Infrastructure to common European e-Infrastructures (liaison with Pan-European e-Infrastructure initiatives) like GÉANT, EGI, regional South-Eastern Europe HPC infrastructure. RENAM is the only national gateway to GÉANT that is realized by 10 Gbps optical connection through Romanian NREN RoEduNet. RENAM is the member of RIPE, TERENA and CEENet associations.

The MD-GRID National Grid Initiative (NGI) was established in 2007 and now is integrating three Grid sites, offering R&E PKI operational support, providing federated identity management, offering other specific informational and computational services. NGI infrastructure provides resources for the national MD-GRID VO and supports international virtual organizations like Biomed and ATLAS. Activities of NGI are focusing on forming of national users' community, organization end users support, analyzing of users' needs, deploying demanded services for user communities. NGI organizes seminars and conferences, on which broadcast the European and regional experience in creating and using e-Infrastructures. For research teams available two local mid-size HPC clusters and they have access to regional HPC resources that are offered by HP-SEE project.

The main areas of complex applications development in Moldova related to weather forecast, climate monitoring, climate change modeling; medical images acquisition, storing, processing and visualization; computational physics; nanotechnology, nano-materials and nanoelectronic discrete devices modeling and computer aided designing of semiconductor devices; economical processes modeling based on games theory algorithms.

The **Ukrainian** Research and Academic Network (URAN) unites approximately 100 universities where 2/3 of Ukrainian students (over 1 000 000) are studying as well as some research institutions. It is operated by URAN Association, non-profit organization, possessing own optical metropolitan area networks in 17 Ukrainian cities 300 km long and 80 km cross-border fiber optic line from Lviv to the Polish state border connected to GÉANT network.

Long distance intercity lines and Internet access bandwidth are leased from three other operators, including UARNET, state enterprise owned by NAS, which is serving the corporative network of NAS "AMOD" (Akademichna Merezha Obminu Danykh). Four interconnections between URAN and UARNET: 10 Gbps in Kiev and in Lviv, 1 Gbps in Kharkiv and Donetsk allow to AMOD users to use the 1 Gbps connection to GÉANT.

Well-developed NREN guarantees successful functioning Ukrainian Grid infrastructure and exploring Grid technologies and applications. The Ukrainian National Grid (UNG) unites now 41 grid-clusters (31 clusters in NAS of Ukraine, 10 clusters of the leading universities and educational institutes), operating in 11 scientific centers of Ukraine. Since 2010 the State program "Implementation and application of Grid technology for 2009-2013" is in progress. After 2013 further development of the Ukrainian Grid-infrastructure is planned under support of NAS of Ukraine. Every year about 40 thematic projects are carried out within the operating State program in the following directions:

- High energy physics, astrophysics and astronomy;
- Life sciences, in particular, molecular and cellular biology, modeling of neural systems; medical applications (medical data bases, processing of medical images and data);
- Earth sciences, environment, seismology, climatology, predictions of the catastrophic natural phenomena;
- Solid and soft matter physics, property and structure at atomic and molecular level;
- Materials science, nanotechnologies, creation of materials with the desired properties.
- Development of Grid infrastructure and adaptation of Grid applications, Grid-services, user web interfaces for Grid-services and applications.

Many of the projects are dealing with improvement of Grid technologies and Grid-services, upgrading of computing resources, storage and improvement of big data processing. Since 2011, UNG is collaborating with NorduGrid, contributing to the development of ARC middleware and services. After signature in the end of 2011 of the agreement, cooperation between UNG and EGI in technological area had begun. UNG signed in 2006 the Memorandum with WLCG (Worldwide LHC Computing Grid) that allowed providing resources of Tier-2 clusters for ALICE and CMS experiments at the Large Hadron Collider in CERN. Some common projects in the field of biology, Earth sciences and cooperation within projects devoted to studying of the water problems of the Black Sea basin have big prospects.

Countries from EaP region are participating in various e-Infrastructure development initiatives funded by European Commission. All countries engaged in the following large scale projects:

- European Grid Initiative: Integrated Sustainable Pan-European Infrastructure for Researchers in Europe (InSPIRE).
- Multi-Gigabit European Research and Education Network and Associated Services (GN3plus).

In addition, countries are involved in regional infrastructure and policy projects:

- High-Performance Computing Infrastructure for South East Europe's Research Communities (HP-SEE).
- Experimental Deployment of an Integrated Grid and Cloud Enabled Environment in BSEC Countries on the Base of g-Eclipse(g-Eclipse).

- Policy dialogue in ICT to an Upper level for Reinforced EU-EECA Cooperation (PICTURE).

3. APPROACHES TO THE e-INFRASTRUCTURE DEVELOPMENT

Following e-Infrastructure definition there are two big layers of the system: networking layer, which is the basis for communications between application and service layer. For the networking layer is extremely important the possession of optical fiber by NRENs for the sustainable development and implementation of new services. Optical fiber based networks have wide variety of network design approaches and technology choice. Such networks ensure the fixed cost of use of the infrastructure and at the same time provide the scalability up to Tbps, as the network grows.

Still only 5-7 years ago European research networking faced digital divide, clearly visible at the eastern and southeastern borders of European Union. Very expensive, low speed networks of eastern states (mainly based on communication channels provided by local telecoms) were no match to multi-gigabit networks of EU countries (usually based on own dark fiber infrastructure or relatively cheap, high capacity channels procured on competitive basis). In this situation, EU research teams were virtually cut-off from potential non-EU partners, simply because of the limitations of research networking infrastructures in Eastern Europe. Above observations are confirmed by the relevant study of SERENATE project, which concludes that [4]:

- The digital divide exists in research networking in Europe and to such a level that, if uncorrected, will prevent the goal of equal opportunities for researchers being attained;
- In the countries most affected by the digital divide the case for effective government support for research networking needs to be made. This is an area where the European Commission, national governments, TERENA and the NREN community all need to play their part;
- Research exclusion is a real risk in most of the EU Neighboring Countries and that this will obstruct attempts to build common European Research Area.

These conclusions lead to a wide belief, that only optical infrastructures, better owned by NRENs, can help to bypass the disadvantages related to local conditions (such as poor infrastructure and market development, insufficient funding, etc.) and bridge the gaps between various, very demanding research communities, such as radio astronomy, high energy physics, environment monitoring and modeling, and many other areas of common interest.

We consider utilization of Dark Fibre (DF) paradigm as the most appropriate solution for NREN optical infrastructures implementation. This concept should be well understood in order to properly evaluate the economical aspects of such infrastructure development. Fibre acquisition and operations involve new cost categories that have to be recognized and added to the economical model of operations of fibre based NRENs. In addition, the economical assessment shall be done for a longer period – DF is usually a long-term acquisition and shall be evaluated as such. NRENs DF interconnections, so called Cross Border dark Fibre – CBF concept, is now widely used by European NRENs. In GÉANT network CBF connections are used for optimization of GÉANT optical backbone construction. CBF connectivity is already in service between many NRENs in Western and Central Europe.

In 2006 - 2007 NRENs from EaP region were involved in European Commission project "Distributed Optical Gateway from Eastern Europe to GÉANT (Porta Optica Study - POS)". The project had its aim to investigate most suitable approaches for realization of regional optical infrastructure that could be further integrated to GÉANT. During the project realization a detailed investigation of possible solutions to build fiber optic infrastructure for connecting R&E networks of the Eastern European countries (including Armenia, Azerbaijan, Belarus, Georgia, Moldova, Ukraine) to GÉANT network was performed. In the project there were elaborated recommendations to build a number 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 Romania, Poland and Turkey. As a result of these investigations the direct optical links were established between NRENs from Romania and Moldova, Poland and Ukraine and Poland and Belarus.

Thus, three countries from the region (Moldova, Ukraine and Belarus) have sufficient cross-border connectivity for today's needs. The most important issue here is the provision of connectedness of the network as a whole, which would provide redundancy for all the countries involved. The study underway must concentrate on this aspect of the EaP countries connectivity problem.

At the same time, the problem of the digital divide is still relevant for the countries of the South Caucasus. Dialogue between EaP NRENs and EU experts initiated in 2012 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 networking segment creation. The various approaches of the regional European Eastern Partnership networking e-Infrastructure development and its integration to GÉANT were discussed. The summary of proposed by regional experts vision is:

- Build Eastern Europe arc – realize CBF connections that will cover PL-BY-UA-MD-RO;
- Create Caucasian CBF links like GE-AM, GE-AZ;
- Realize submarine fiber connection of the Caucasian optical hub to Odessa, Ukraine (or alternative – to Varna, Bulgaria) by upgrade submarine Black sea equipment and increasing the bandwidth to 100 Gbps;
- Implement terrestrial connection through Turkey of Caucasian optical hub to the regional EaP infrastructure as a second solution;
- Upgrade of each NREN critical PoPs to 10 Gbps or more (update communication equipment of the principal PoPs in all EaP countries);
- To ensure connection of the EaP Eastern Europe arc and the whole EaP infrastructure through at least 2-3 existing PoPs of GÉANT (Poznan, Bucharest).

As a short term approach for integration of the EaP regional infrastructure to GÉANT experts proposed the following actions:

- Realization of the CBF connections to the existing GÉANT PoPs:
- Using existing CBF connection of Moldovan NREN and create new CBF connection Ukrainian NREN to the PoP in Bucharest (by using RoEduNet infrastructure);
- Using existing CBF connections of Belarusian and Ukrainian NRENs to the PIONIER PoP in Poznan;
- Creation of CBF peering and alternative GÉANT access connections – MD-UA; UA-BY;
- Creation of the Caucasus optical segments and their integration with Eastern Europe part of EaP regional infrastructure over Black sea or Turkey. Ensure its connection to GÉANT PoP.

Possible scheme of regional connections implementation investigated by EaP NRENs and European experts during preparation of the event "e-Infrastructures in Eastern Partnership Countries" held in December 2012 in Chisinau is shown in the figure 1.

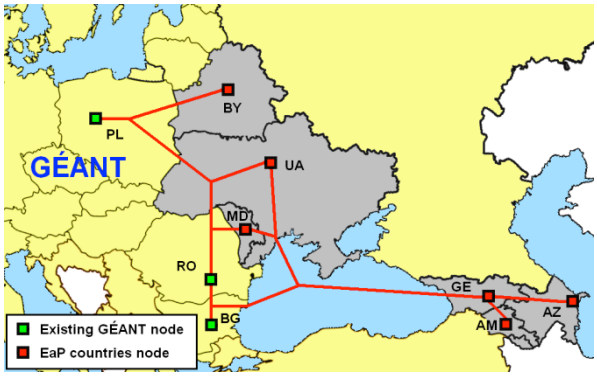

Fig 1. Possible optical connections implementation for EaP region.

These aspects of network and services development were further elaborated in TEPID (Towards Eastern Partnership countries e-Infrastructure Development) initiative and discussed in May 2013 in Kiev during CEENGINE NRENs Users Workshop [5]. Three main priority areas were identified:

- High-speed fiber optic connectivity;
- Data processing facilities;
- Scientific and research information exchange.

In addition analysis of the needs of the users indicates high demand for the following services:

- Provision of easy and widely available access to digital versions of scientific publications (books, journals, databases, etc.) by leading scientific publishing houses;
- Easy access to DOI acquisition for scientific publications and achievement of publishing systems interoperability of EaP countries with global Reference Databases of scientific information;
- Free access to GÉANT and Internet for university students through the deployment of WiFi connectivity in universities and university dormitories, etc.
- Setting up of data-centers and provision of their services to the scientific community.

4. CONCLUSIONS

During the last few years an important development of e-Infrastructure in Eastern Partnership countries has been made, however, there is still a significant gap between the developed European countries and region.

Support from Governments and European Commission for the further development of e-Infrastructure in the region is essential for the integration of scientific potential of these countries in the European Research Area.

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