Regional E-Infrastructure and Services for Research and Education in EAP Countries

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Abstract

In the paper considering approaches and solutions for development of modern regional e-Infrastructure resources for providing specific services to the research and educational communities in countries supported by European Eastern Partnership Programme. Over the past several years the dependence of research and education on access to high-speed networking infrastructures, to large-scale computing and other e-Infrastructures' services is rapidly increasing. e-Infrastructure designates a new generation of integrated ICT based resources, services and is widely considered as a key enabler for scientific and social development. Such infrastructures represent a distributed medium based on high-bandwidth networks, distributed Grid computing, High Performance Computing (HPC), scientific Cloud resources and respective data repositories. The focus is made on describing the various services that are deploying in the Eastern Partnership countries to support educational and research activities in universities and research centers. Argued importance of developing of Research and Educational networks as a key e-Infrastructures' enables. Described expected outcomes of regional projects supported by European Commission in the area on regional infrastructures and modern services deployment for research and education.

Keywords – regional networking infrstructure, e- infrastructures and services for reserch and education
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1. Introduction

In the Eastern Partnership (EaP) countries (Moldova, Belarus, Ukraine Armenia, Azerbaijan and Georgia) are developing national e-Infrastructure components like Grid, HPC and Cloud computing facilities, electronic libraries, scientific data repositories, etc. Taking into account European models, in EaP countries organizational structures for the support of modern collaborative research – National Research and Education Networks (NREN), National Grid Initiatives (NGI) and HPC users' associations were established. They are actively participating in the regional and pan-European projects, including initiatives focused on integration in the leading European e-Infrastructures. In the region there are many qualified research teams intensively using computational and

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informational resources provided at national and European levels (Bogatencov P., et. al., 2014).

It should be mentioned that during last few years important development of e-Infrastructure in EaP countries has been made, however there is still a significant gap between the developed European countries and the EaP region. Hence support from National Governments and EU 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. That is why since 2016 EaP countries are participating in the regional initiative named EaPConnect that is supported by European Commission in a form of co-funded project and is intending to fill the existing gap.

According to the information provided by NRENs of EaP countries the number of users of various networking services, computing resources and data repositories is constantly growing. Key research applications and services that are developing in the region 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. Accumulated experience of new networking and computing technologies application shows that for more active and effective use of available e-Infrastructure resources and services is necessary to reorganize users' support activities, activate new approaches of interested users' communities engagement, enhance training activities for new and existing users, provide operative consultations for professionals to raise their skills in deployment of new demanded services.

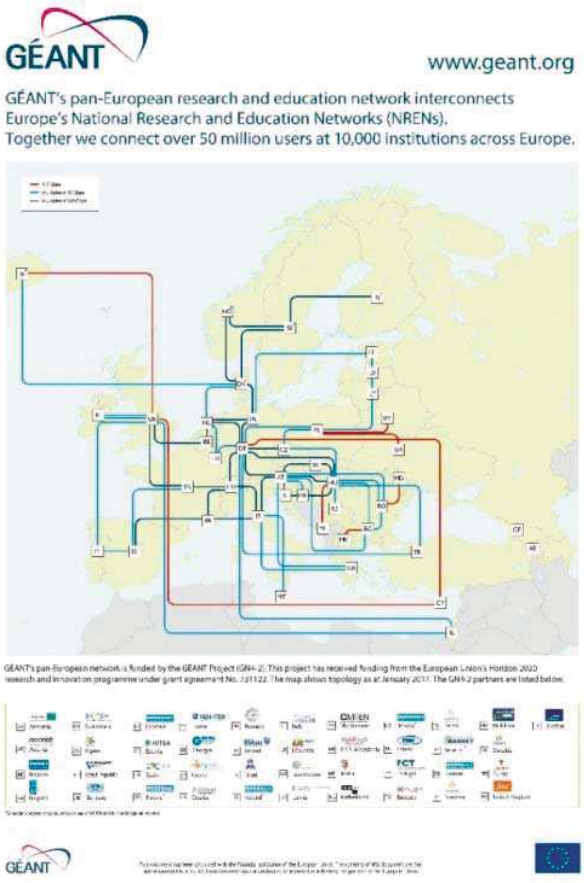
2. Regional Network Facilities

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. A modern network infrastructure is one of the basic components of e-Infrastructure 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 we consider optical fiber based networks that have a wide variety of network design 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.

Pan-European research and education networking infrastructure based on GÉANT network that is interconnecting European national research and education networks (GÉANT pan-European research and education network, 2014). GÉANT network operation and development is supporting by a serious of EU funded projects that include a collaboration between 40 partners represented by 37 European NRENs and NORDUnet (comprising NRENs from Norway, Sweden, Finland, Denmark and Iceland). In total, the project represents 42 NRENs including from EaP countries - Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine. GÉANT provides a high-bandwidth, first-class network infrastructure and services connecting over 50 million

users at 10,000 institutions across Europe. The current GÉANT backbone topology is presented in Fig. 1.

Figure 1. GÉANT backbone topology.



Source: GÉANT pan-European research and education network, 2014

Several initiatives supported by the European Commission (EC) were launched 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 EaP region were involved in the EC project "Distributed Optical Gateway from Eastern Europe to GÉANT (Porta Optica Study - POS)" (EU FP6 Porta Optica Study project, 2008), which aimed at the investigation of the most suitable approaches for realization of regional optical infrastructure that could be further integrated to 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 several recommendations were made to build a number of cross border connections that will

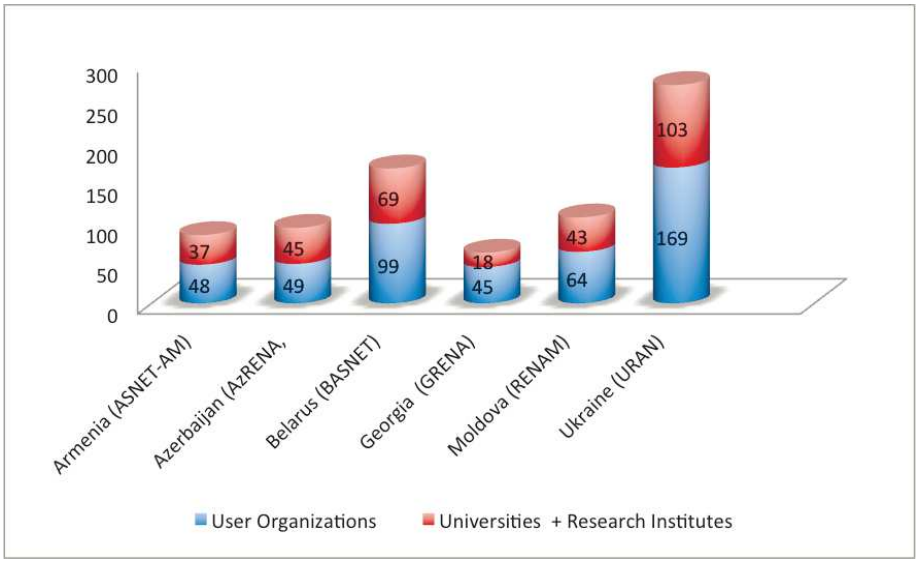
unite neighbor NRENs, determined principal ways to organize connection of elaborated regional infrastructure to GÉANT via Points of Presence in several countries.

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 the both projects 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 Pan-European optical backbone construction.

As a result of these investigations and due to EC support the direct optical links were established between NRENs from Romania and Moldova, Poland and Ukraine, Poland and Belarus. Thus, Moldova, Ukraine and Belarus have cross-border connectivity to satisfy the current needs; however there is a need for development and creation of resilience backup connections to GÉANT network. At the same time, the problem of the "digital divide" is still relevant for the South Caucasus countries. The most important issue is the provision of high bandwidth communications, which would provide redundancy for all the countries involved. The Fig. 2 shows detail information about the organizations using such networking facilities in EaP countries based on data provided by NRENs and some additional information obtained also from GEANT Compendium (TERENA/GEANT Compendium, 2002 – 2016).

Figure 2. EaP NRENs – users' community outreach.



Source: NRENs & TERENA/GEANT Compendium, 2002 – 2016

After the analysis of the provided and available information the following conclusions can be drown:

- Over half of students, lecturers and researchers are served by EaP NRENs;
- Connectivity conditions for Belarus, Moldova and Ukraine are much better compare to Armenia, Azerbaijan and Georgia due to the support from Polish and Romanian NRENs;
- Fraction of scientific traffic is still low compared to the demand on the commodity Internet for EaP countries;
- Costs for clear channel needed to establish GÉANT connectivity are several times more expensive compare to the commodity Internet, especially in South Caucasus countries;
- Internal backbone capacity upgrade to 10 Gbps is required for Armenia, Azerbaijan, Georgia and Moldova; the current backbone capacity for Belarus and Ukraine is sufficient;
- Eduroam mobility service has been deployed in all EaP countries, however the percentage of institutional participation still very low;
- Additional analysis and more close cooperation is necessary for the implementation of the necessary and demanded services in the regional network.

Dialogue between EaP NRENs and EU experts initiated in 2012 and continued later within GN3plus project had 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 a GEANT project experts' team 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. The whole regional network architecture was proposed in the EaPConnect project Concept Note developed by experts from GEANT Association, CEENet and Eastern Partnership NRENs. The proposed regional network structure has clear advantages:

- Fulfills the connectivity and capacity requirements of all EaP NRENs;
- Provides a large capacity increase including to South Caucasus countries;
- Provides backup connection to NRENs;
- Traffic between NRENs in Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine goes mainly via CBF connections over the dedicated network.

As a long term vision that would ensure wider collaboration with EaP countries, in the EaPConnect Concept Note proposed to establish two optical connection arcs:

- North to South connection arc - possibly from Baltic States through Poland, Belarus, Ukraine, Moldova, Romania and further to Sofia and Athens.
- Black Sea – connection from Romania through Moldova, Ukraine, South Caucasus to Turkey and further to Sofia and Athens.

As the kernel of the North to South optical arc in the Concept Note considering creation in the western part of EaP region several CBF connections between EaP NRENs and optical links to neighborhood NRENs from Central Europe that already effectively integrated to GEANT optical backbone (see Fig. 3).

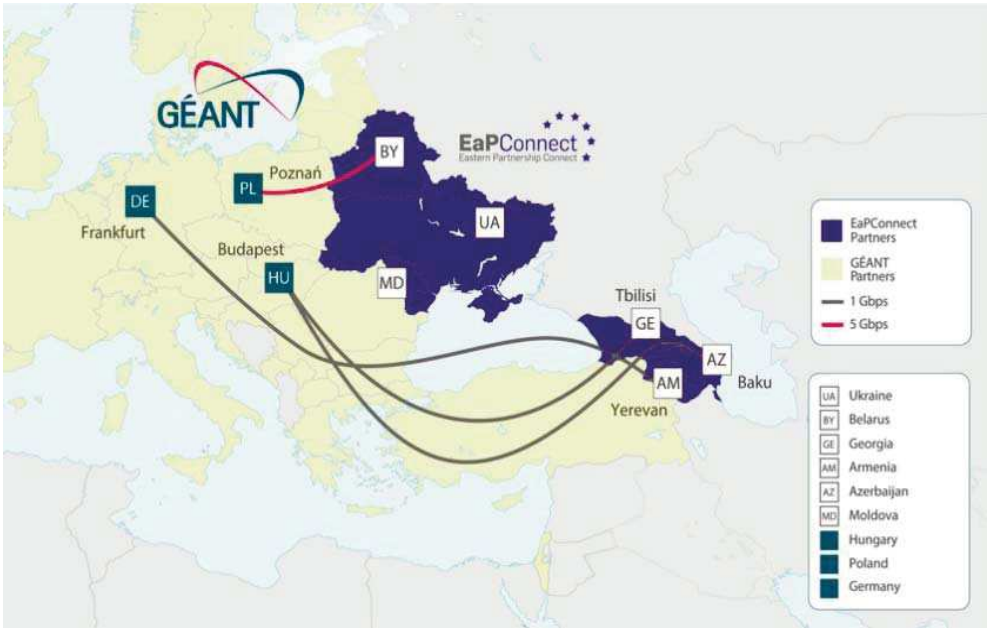
The realization of the first stage of the EaPConnect project networking infrastructure allowed to implement four new direct connections to integrate NRENs infrastructures of Armenia, Azerbaijan and Georgia in GEANT network, create CBF connection between Armenia and Georgia, upgrade (duplicate) existing connectivity of Belarus to GEANT Point of presence (PoP) in Poland and create the second optical link to the new GEANT PoP for Ukraine.

Figure 3. Geographical scheme of EaP North to South optical arc implementation

Source: BOGATENCOV P., et. al., 2014

During the first stage of EaPConnect project realization was elaborated the technical solution for upgrading connectivity of NREN of Moldova to Romanian NREN RoEduNet infrastructure and creation of the second CBF connection for NREN of Moldova to GEANT PoP in Bucharest. The realization of the elaborated technical project plans until the end of 2017. Newly created connections for implementation of the regional networking infrastructure are shown in the Fig. 4.

Figure 4. The first stage of EaPConnect project networking infrastructure development



Source: https://www.eapconnect.eu/wp-content/uploads/2017/07/EAPtopology-Jun2017-1000w.jpg

3. Computing and Data Infrastructures In EAP Countries

The current state of computer and networking technology makes the seamless sharing of computing resources on a global scale. Scientific computing Grids (I. FOSTER, C. KESSELMAN, et al., 2001) make it possible to integrate large, geographically distributed computer clusters and data storage facilities. Recent two decades within different projects (EU FP6 Enabling Grids for e-Science, 2003; EU FP6 Eu DataGrid project, 2006), EU is building the next generation pan-European computing infrastructures providing intensive computation and analysis of shared large-scale databases. SEE-GRID (South East European Grid) (ANTUN BALAZ, et. al., 2011) and BalticGrid (EU FP7 BalticGrid project, 2009) regional initiatives pushed to deploy sustainable national Grid infrastructures in the EaP countries and to integrate into the pan-European and worldwide e-Infrastructures through the interconnection of the regional infrastructures. Armenian, Georgian and Moldavian infrastructures were part of the SEE-GRID, and Ukrainian and Belarusian infrastructures were part of the Baltic Grid. In parallel NGIs have been established in EaP countries, which manage the computing resources provided to the national users' communities and integrated into the European and regional computing infrastructures. In addition, NGIs are focusing on forming of national users' communities, organization end user support, analyzing the needs of users', deploying demanded services for user communities.

In 2010 the new European Grid Initiative was launched. The goal of EGI-InSPIRE project (EU FP7 EGI-InSPIRE project, 2014) is to establish a sustainable European Grid

infrastructure and provide European scientists and their international partners with a sustainable, reliable distributed computing infrastructure that can support their needs for large-scale data analysis and simulations. 51 national and international institutions from Europe and Asia Pacific region are partners of the project, among them organizations from Armenia, Belarus, Georgia, Moldova and Ukraine. Information about Grid and cloud computing facilities in EaP countries (GRID STATISTICS, 2010-2015) is presented in table 1.

Table 1. Computational resources in eap countries

	Total Number of Sites	Number of Sites in EGI	Physical CPU	Logical CPU	Storage Capacity	Supported VOs
Armenia	8	2	148	592	27	6
Azerbaijan	3	0	84	336	72	4
Belarus	6	1	64	228	28	2
Georgia	2	1	74	300	28	5
Moldova	3	2	48	192	11	5
Ukraine	41	10	938	2372	455	45

Source: GRID STATISTICS, 2010-2015, BOGATENCOV P., et. al., 2014

The following conclusions can be made:

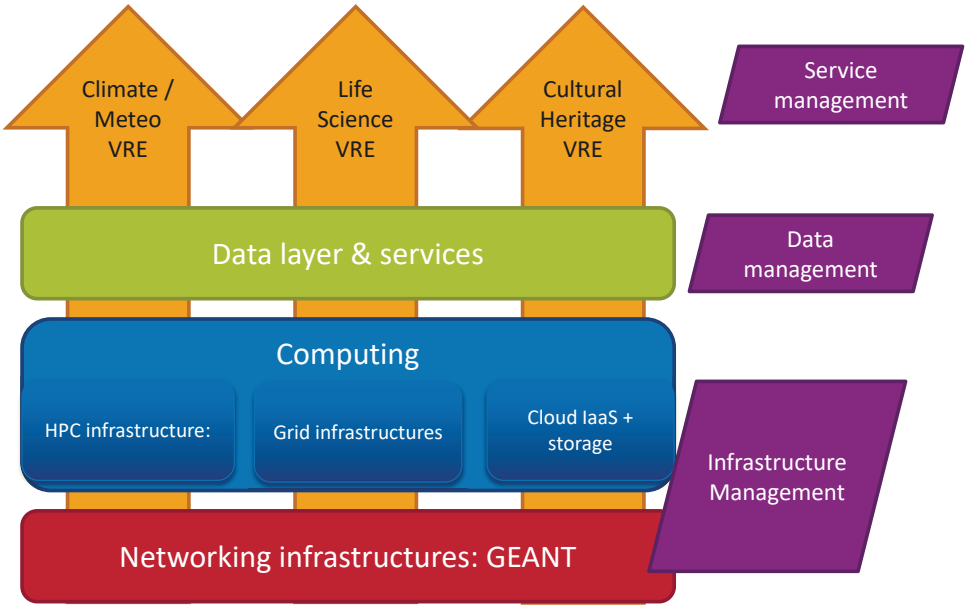
- All EaP countries are involved in distributed computing activities by providing computational resources to users;
- Only Azerbaijan resources are not included in EGI;
- Significant part of research computations is performed on HPC resources not included in EGI;
- Computational and storage resources provided to EGI are not large except Ukraine;
- Different EGI VOs are supported at 16 sites that included in EGI;
- Armenia, Belarus, Moldova and Ukraine support CERN related VOs (ALICE, ATLAS, CMS, LHCb).

Three EaP countries Armenia, Georgia and Moldova are engaged also in realization of the regional e-infrastructure development project “VRE for regional

Interdisciplinary communities in Southeast Europe and the Eastern Mediterranean (VI-SEEM)" (H2020 VI-SEEM project, 2015).

The project objectives addressed to the unique expertise focused on development of various e-Infrastructure components launched during the various e-Infrastructure initiatives realization in the region. The specific e-Infrastructure developments will provide an integrated distributed data handling platform upon which specific Virtual Research Environments (VRE) will be built. The integrated platform encompasses all layers including the networking and computing resources, and adding the specific data (and related data management services), software and tools relevant for the regional multi–disciplinary scientific communities. The Fig. 5 below depicts this integration over layers across the 3 selected communities.

Figure 5. Integration of the 3 selected regional communities over the layers of the integrated data processing platform



Source: H2020 VI-SEEM project, 2015

The overall VI-SEEM project aim is to provide user-friendly integrated e-Infrastructure platform for VREs in Climatology/Meteorology, Life Sciences, and Cultural Heritage for the region of South East Europe by linking compute, data and visualisation resources, as well as services, software and tools. The detailed objectives of the project include the following:

- Provide for the scientists from the region access to state of the art connectivity, computing and storage resources available in the region and help further to develop new resources across the region.
- Integrate the underlying e-Infrastructure layers with generic/standardised as well as domain-specific services for the region. The latter are leveraging on existing

tools with additional features being co-developed and co-operated by the scientific communities and the technology and e-Infrastructure providers, thus proving integrated VRE environments. The approach is service-driven in terms of service components and definitions, and their invocations.

- Promote capacity building in the region and foster interdisciplinary approaches.
- Provide functions allowing data management for the selected VREs, engage the full data management lifecycle and provide data interoperability across disciplines.
- Provide adequate user support and training programmes for the user communities in the region.
- Bring high level expertise in e-Infrastructure use to enable research activities of international standing in the selected fields of Climate, Life Sciences and Cultural Heritage

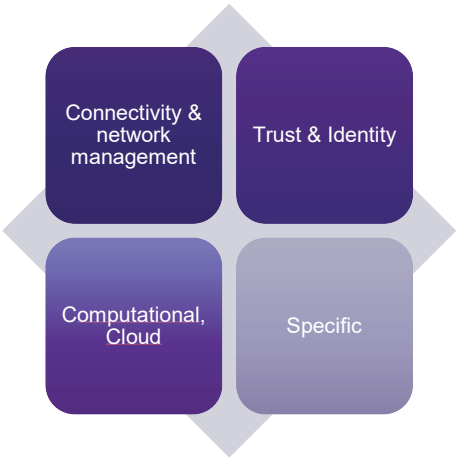
4. E-Infrastructure Services for Regional Research and Educational Communities

On the base of comprehensive analysis produced during EaPConnect and VI-SEEM projects proposal elaboration the following areas of development determined as particularly important for the EaP region research and educational communities:

- *ICT for education, research and digital information services*. Universities, research institutes, libraries and cultural centres need to enhance their activities and be involved in information digitization as well as new technologies for digital information access development. Providing access to digital libraries, e-services for access to cultural heritage and e-learning resources are amongst the highest priorities.
- *Electronic governance (e-governance) in education and research, including intelligent information* management. EaP countries are planning to create new services for research and educational communities with the help of new ICT solutions and reformed regulatory framework. The joint development of agreed solutions is an important task.
- *Health*. ICT for Health is one of the most significant societal challenges in EaP countries, as well as in the EU. It is important to develop interoperable solutions and standards within this field as well as to foster technical solutions implementation in EaP countries that are in line with the best European practices.
- *Connect to state of the art scientific research infrastructures in Europe*. Although there are several EU research centres with strong collaboration with EaP countries, this is technically limited by inefficient connectivity and lack of the necessary local e-infrastructure resources. Examples of domains of interest are Grids and Cloud Computing, nanotechnologies and microelectronics.

During the initial stage of the EaPConnect project realization the analysis of the most demanded services was produced . The services developing in EaP region enables to support the needs of researchers, students, stakeholders and other user communities both in a National and a Regional Levels. All services proposed for implementation are grouped as presented in Fig. 6.

Figure 6. Types of e-infrastructure service acessible for EaP research and educational communities



Source: EU FP7 CEENGINE project, 2012

Elaborated plan of e-Infrastructure services implementation includes the following grouped services recommended for priority deploying by EaP NRENs:

Connectivity & network management:

- *eduroam* - the pan-European service providing secure access to wireless networks on campuses from mobile devices effectively enabling mobility of researchers and students;
- *perfSONAR (PERFormance Service Oriented Network monitoring ARchitecture)* - is a network measurement toolkit for running performance tests across multiple domains which helps to identify and isolate network problems.
- *Software Defined Network* (SDN) - is new paradigm and innovation in networking giving new possibilities in network utilization: reduce operational cost for network management; centralized network provisioning; hardware savings and reduced capital expenditures; guaranteed content delivery. The service allows to users themselves to manage the channel parameters of the owned channels.

Trust & Identity:

- *Web Single Sign-On* - the federated service available to connect campuses via identity federations.
- *eduGAIN* - emerging service in the GÉANT context around identity federations. Create inter-federation environments allowing the collaboration that is facilitated by national identity federations to reach beyond borders and support pan-European collaboration.

Specific:

- *Open Access initiative* - a new value added service for NRENs that is dedicated to support and promote open access to electronic publications according to the EC Directive 2001/29/EC, the Budapest declaration and other documents in that field. Open Access directories provided as a service by NRENs could offer a very

convenient way for EaP countries researchers to publish their work and to make it known at international level.

- *Real-time musical collaboration LOLA* (LOw LAtency audio visual streaming system) - aims to enable real time musical performances where musicians are physically located in remote sites, connected by advanced network services, like the ones provided by the NRENs and GEANT and other high-speed international backbones.
- *Digitization of Cultural Heritage* - to support digitisation technologies and development of digital libraries by providing advanced data digitization, networking, computational and data storage facilities. Strength on balance collaboration and promotion of individual institutions to build virtual repositories on the top of regional digital libraries.

Computational and data storage serviced described in detail in the section III. Computing and Data Infrastructures In EAP Countries.

5. Conclusions

During the last few years important development of e-Infrastructure in EaP countries has been made, however there is still a significant gap between the developed European countries and the EaP Countries. Support from Governments and EC for the further development of e-Infrastructure and associated services in the region is essential for the integration of scientific potential of these countries in the European Research Area, such as European Research Infrastructures with global impact.

The realization of regional projects like EaPConnect and VI-SEEM will significantly contribute to the high quality networking infrastructure and well developed informational services deployment in EaP region.

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