

# FP7 Research Infrastructures

## BSI

### Black Sea Interconnection



Black Sea Interconnection

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## Deliverable D2.2

### Networking Topology Options and Implementation Approaches

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## Preface

The Black Sea Interconnection (BSI) project aims to achieve a high-speed network backbone among the NRENs of the South Caucasus countries (Georgia, Azerbaijan and Armenia) and enable connectivity to the pan-European GÉANT2 network. The BSI project intends to introduce new technologies and services to the Information Society in those countries and be an important leap towards the integration of those countries' scientific potential with the European Research Area. The project involves the development of strategies for interconnecting the existing infrastructures in the region, realization of the connections and supplying operational support for the established network. The project beneficiaries are TUBITAK, GRNET, CEENET, DANTE, GRENA, AZRENA and NAS RA.

The main objectives of the BSI project are:

1. Building a proper regional research and education network among South Caucasus and connecting it to GÉANT2.
2. Integration of South Caucasus scientific potential to Europe by successfully disseminating the infrastructure and promoting the ICT projects in South Caucasus countries.
3. Fostering collaboration between homogenous scientific communities by identifying the involved communities in the region and establishing mechanisms for knowledge transfer.

The BSI project has started its activities on March 2008 and is planned to be completed by the end of February 2010. BSI is coordinated by TUBITAK. The total budget of the project is 1 861 908 € and it is co-funded by the European Commission's Seventh Framework Programme for Research Infrastructures and National budgets of South Caucasian Countries.

The BSI consortium will achieve the following milestones:

Milestone number	Milestone name	Date	Status
M1	Kick-off meeting	M1	√
M2	Project management information system established	M1	√
M3	Promotional package available	M4	
M4	NRENs requirements collected and analysed	M2	√
M5	Technical and operational requirements analysed	M3	√
M6	Tenders prepared	M3	
M7	Suppliers selected	M4	
M8	Connectivity and equipment contracts signed	M5	
M9	Final BSI topology determined	M5	
M10	Operation of the regional networking infrastructure offering access to BSI NRENs GÉANT2 access	M6	

M11	Management framework in place and stable network operation	M8	
M12	Services/tools selected	M10	
M13	Successful completion of first period project review	M12	
M14	Workshop/Conference Track in region organized	M20	
M15	Services/tools deployed	M20	
M16	Successful completion of project - final project review	M24	

The project will issue the following deliverables:

Del. no.	Deliverable name	Nature	Dissemination Level	Date	Status
D1.1	Project Management Information system	R	CO	M1	√
D1.2	Network Acceptable Use Policy	R	PU	M4	
D2.1	Requirements capture and an analysis	R	PU	M1	√
D2.2	Networking topology options and implementation approaches	R	PU	M2	√
D3.1	Tender progress report	R	CO	M4/M5/M6	
D3.2	Network topology	R	PU	M6	
D4.1	Network implementation and equipments configuration	R	PU	M9	
D4.2	Operational procedures and management framework	R	PU	M10	
D4.3	Networking services and tools specifications	R	PU	M12	
D4.4	Deployment of essential network services and management tools	R	PU	M21	
D5.1	Web site, docs repository and mailing lists	R	PU	M1	√
D5.2	BSI Promotional material	O	PU	M8	
D5.3	Stakeholders meetings in beneficiary countries	R	PU	M15	
D5.4	Report on awareness and liaison activities	R	PU	M23	

**R** = Report , **O** = Other , **PU** = Public, **CO** = Confidential (only for members of the consortium incl. EC).

## Executive Summary

### What is the focus of this deliverable?

This deliverable aims to assess all possible implementation approaches and topology options of GÉANT2–BSI interconnection based on the information obtained from the operators in the region. The pros and cons of these topology options will be assessed in terms of their financial, political, economical, technical and managerial merits and sustainability and time scale.

### What is next in the process?

The outputs of this will be used as input to procurement documentation. Pros and cons of each option will be further studied during the evaluation of the offers by the connectivity suppliers.

### What are the deliverable contents?

Section 1 briefly introduces the deliverable. Section 2 figures out the connectivity options available in terms of leased capacity or dark fiber. Section 3 gives an overview of possible topology options which are further investigated in terms of their financial, political, economical, technical and managerial merits and sustainability in Section 4. Finally, Section 5 concludes the deliverable.

### Conclusion

In Deliverable D2.2, all the feasible network topology options were studied and evaluated in terms of their financial, political, economical, technical /managerial and sustainability merits. The available budget as well as the political constraints is taken into account. The resulting evaluations are expected to be guidelines for the tendering process.

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- [1] BSI Consortium, “Black Sea Interconnection (BSI), Annex-I Description of Work”, 2008
- [2] BSI Deliverable D2.1 “Requirements Capture and an Analysis”, 22.04.2008
- [3] Porta Optica Deliverable D2.2v2 “Special Issues Related to South Caucasus”, 21.06.2007
- [4] Porta Optica Deliverable D3.3v3 “Fiber Network Development Plan”, 17.10.2007

## Introduction

The BSI (Black Sea Interconnection) project intends bridging the digital divide that exists between the South Caucasus countries and Europe by establishing a regional research and education network in the South Caucasus and connecting it to GÉANT2. The existence of interconnections between the South Caucasus countries and connection to GÉANT2 with reasonable capacities will enable introduction of new services to the region and will be an important step towards the integration of the scientific potential in the region with Europe.

This document puts forth the interconnection opportunities in the region in order to provide an input to the tendering process. Information about interconnections is collected through the answers of various telecom operators in the region to the Request for Information (RFI) questionnaire and from the results of the Porta Optica Study.

## 1. Availability of Connectivity

### 1.1. Availability of Leased Connectivity in South Caucasus

9 operators operating in the region were contacted by consortium members to reveal the opportunities for leased capacities. The summary of the responses acquired from the operators is presented in the Table.1:

Options for Interconnectivity	Capacity	Available Operators
<b>Georgia-Azerbaijan</b>	2-155 Mbps	6 operators+ 1 operator through partner
<b>Georgia-Armenia</b>	2-155 Mbps	8 operators+1 operator through partner
<b>Azerbaijan-Armenia</b>	-	No fiber
Options for Connectivity to GÉANT2	Capacity	Available Operators
<b>Georgia-GÉANT2</b>	34-155 Mbps	7 operators+1 through partner (To Stockholm, Frankfurt, Istanbul)
<b>Azerbaijan-GÉANT2</b>	34-155 Mbps	1 operator (to any European city)
<b>Armenia- GÉANT2</b>	34-155 Mbps	1 operator through partner

**Table. 1: Responses to RFI for Leased Connectivity**

The connection types revealed to be available in the following sections will be used in various combinations in the development of network topology options later on.

#### 1.1.1. Availability of Leased Interconnectivity among South Caucasus NRENS

In response to the RFI, 6 operators have responded that they can provide interconnectivity between Georgia and Azerbaijan with capacities ranging from 2 Mbps to 155 Mbps. Even more operators were willing to lease interconnectivity between Georgia and Armenia with similar capacities. However, no direct interconnectivity options are available between Azerbaijan and Armenia because there is no fiber connecting these countries.

### 1.1.2. Availability of Leased Connectivity to GÉANT2

As can be seen in Table.1, most of the operators who can provide interconnectivity among South Caucasus Countries are also capable of providing connectivity between Tbilisi (Georgia) and various GÉANT2 PoPs/Nodes with capacities ranging from 34 to 155 Mbps. Stockholm, Frankfurt and Istanbul are possible termination points for the connection from Georgia to GÉANT2. More options may arise as a result of the tendering process.

For the case of leasing capacity between Azerbaijan and GÉANT2, one operator has responded that they can provide leased connectivity to any European city via Georgian and Turkey's SDH optical network of TRACECA with capacities ranging from 2 to 155 Mbps.

GÉANT2 connectivity from Armenia is possible in partnership with the Georgian providers.

### 1.2. Availability of Dark Fiber

According to the results of the Porta Optica Study which are also supported by the answers of the operators to the RFI, leasing or purchasing dark fiber opportunities are very restricted and expensive both for the interconnections between the South Caucasus countries and the international connections from the region.

Following quotes from the Porta Optica Study will be informative to give a broad picture about the availability and pricing of dark fiber:

“There is no possibility to obtain (lease or purchase) DF along the path between Tbilisi-Istanbul, Tbilisi-Yerevan, Tbilisi-Batumi, Poti-Novorossiysk.

There exists an offer for fiber lease (10 year IRU) Sofia-Varna-Poti-Tbilisi with total cost approximately 6,500,000 €

The current status of the telecom market in the region and the neighbouring countries is expected to become more competitive in the near future. Until then the best option will be to connect Southern Caucasus countries research networks to other NRENs through leased capacity instead of fiber leasing because of high cost or fiber unavailability as has been previously stated by Porta Optica Study.

## 2. Topology Options

The connectivity options that revealed to be feasible in the previous section are used to develop different network topology options in this section. The topology options will be studied in three main categories in terms of the connectivity from the countries in South Caucasus region to GÉANT2. In accordance with the Sub-objective.1 and 2 of the BSI project, all the topology options are developed to ensure a minimum of 34 Mbps connection capacity to the regional network backbone, and a minimum of 100 Mbps connection to GÉANT2 with an equal share for each beneficiary. Thus, the connection capacities that will be seen in the following topologies are only the minimum values and can be increased according to the prices obtained from the tender provided that each country has an equal share of minimum 34 Mbps connection capacity to GÉANT2.

### 2.1. Centralized Topology Options

Centralized Network Topology refers to the establishment of a regional network among South Caucasus countries which in turn will be connected to GÉANT2 from a single point. This is a topology type where the intercommunication between the South Caucasus countries will be enabled over this regional network and will not need to travel over a GÉANT2 PoP. Only the traffic targeted to GÉANT2 will occupy the uplink to GÉANT2.

According to the information obtained from the operators, it seems possible that this single connection to GÉANT2 can be made from any of the three countries in the region. Taking into account that an interconnection is not possible between Azerbaijan and Armenia, the following Centralized Topology Options can be developed.

#### 2.1.1. Georgia as the Center

This topology refers to a hub-and-spoke topology with Tbilisi of Georgia being the hub and two other countries are connected to Georgia with equal capacity links. Georgia, in turn, is connected to GÉANT2 with a capacity that will enable all three countries to have an equal share for GÉANT2 connection. As far as the contacted operators have acknowledged, the termination point in GÉANT2 can be Stockholm, Frankfurt or Istanbul.

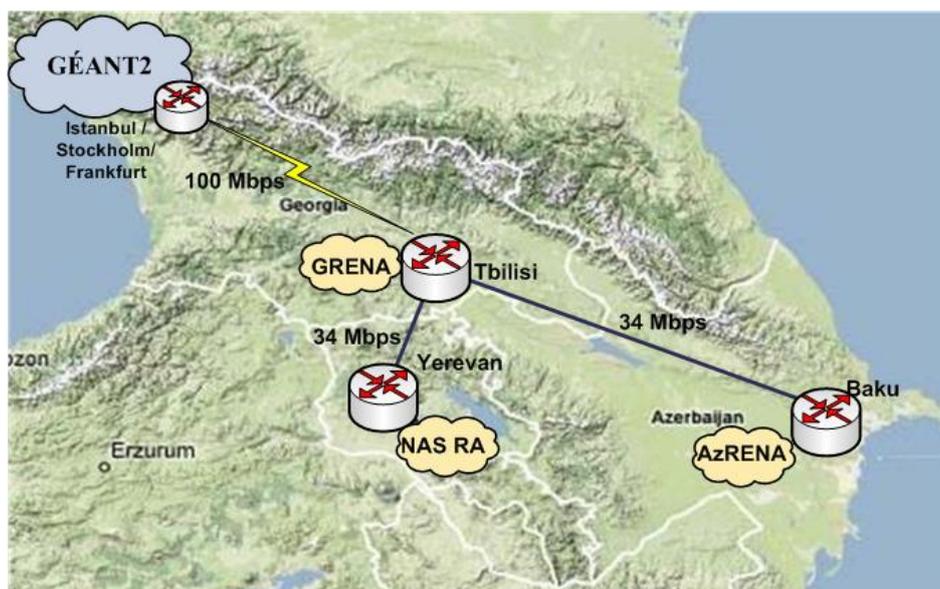


Figure. 1 Centralized BSI Network Topology with Georgia being the center

### 2.1.2. Armenia as the Center

In this topology option, Yerevan of Armenia will be the point of connection to GÉANT2 for the regional network which is a little different from the one discussed above. Because of the infeasibility of an interconnection between Armenia and Azerbaijan, the regional network is a linear one rather than a hub-and-spoke network. This necessity of regional network's being linear requires that the interconnection between Armenia and Georgia to have a double capacity of the one between Georgia and Azerbaijan which may increase the number of interfaces needed for interconnections. Increased number hops from Azerbaijan to GÉANT2 are another issue to be considered.



Figure. 2 Centralized BSI Network Topology with Armenia being the center

### 2.1.3. Azerbaijan as the Center

Similar to the previous option, this network topology option also requires a linear regional network with additional interconnection capacity compared to the topology in 2.1.1. In this topology, Baku of Azerbaijan will be the point of connection to GÉANT2. The termination point in GÉANT2 can be any node in Europe as expressed by one of the operators. This topology also requires more interfaces than the topology in 2.1.1 and increases the number hops from Armenia to GÉANT2.

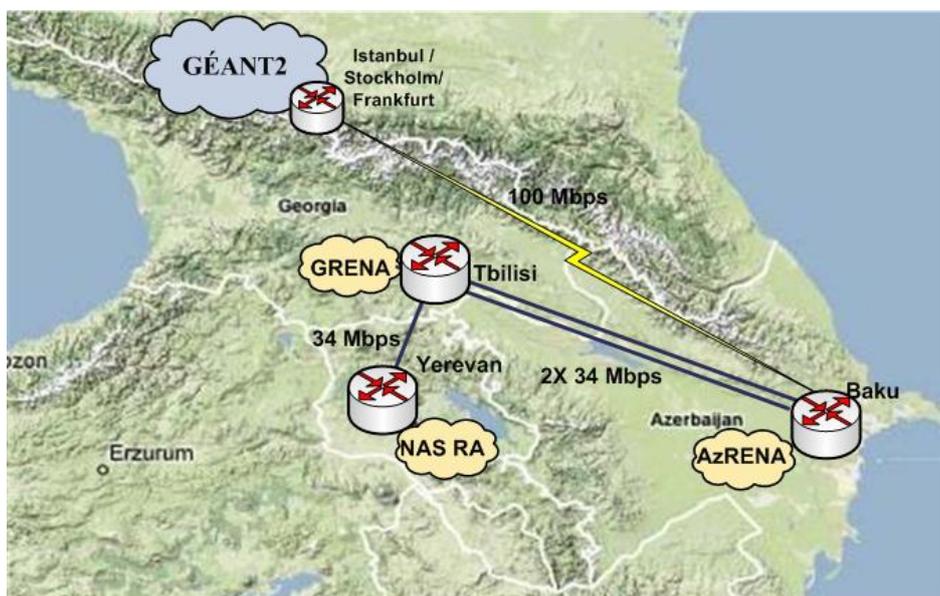


Figure. 3 Centralized BSI Network Topology with Azerbaijan being the center

## 2.2. Decentralized Topology Option

Decentralized Network Topology option does not include the establishment of a regional network among South Caucasus countries, but rather refers to a case where each of the three countries is directly connected to GÉANT2 with equal capacity links. This is a topology type where all the traffic between the South Caucasus countries will travel flow through GÉANT2 links.

Such an option can only be expected when the cost of connectivity to GÉANT2 from each country is unexpectedly low compared to the regional cost of interconnectivity as a result of the tender.

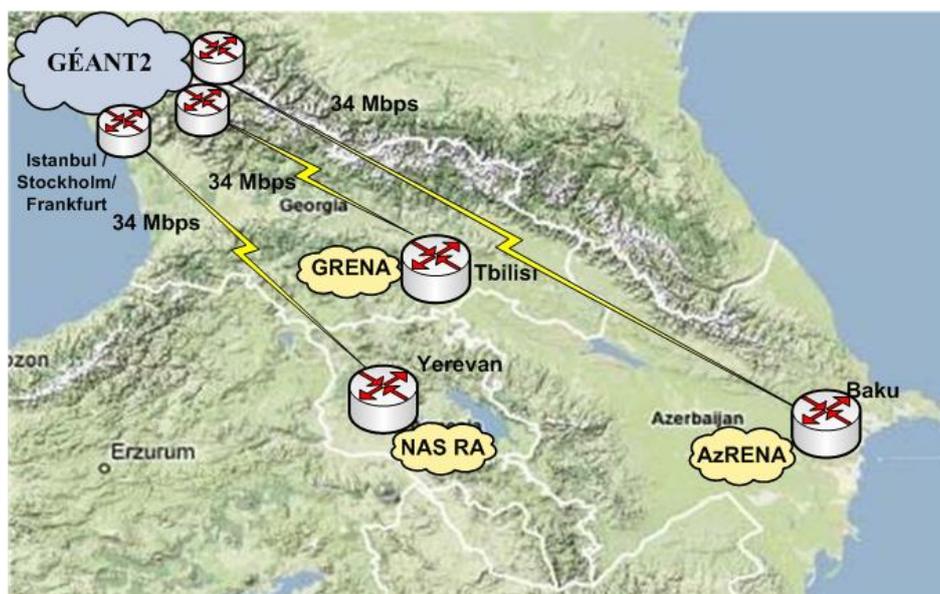


Figure. 4 Decentralized BSI Network Topology

## 2.3. Hybrid Topology Options

Hybrid Topology options are combinations of the Centralized and Decentralized Topologies in the sense that they introduce more than one direct connection to GÉANT2 from the region but rather assume that each country does not have a separate connection to GÉANT2. Different dual combinations of the three countries are connected to each other and have a single point of connection to GÉANT2 from one of the countries, while the third country has a separate uplink to GÉANT2.

This option, as well as the decentralized option, can arise in the unlikely case that the cost of interconnectivity in the region is higher than the cost of connectivity to GÉANT2 for one of the countries.

### 2.3.1. Hybrid Topology Option-I

In this topology, Georgia and Armenia are connected to each other and to GÉANT2 from Tbilisi of Georgia, while Azerbaijan is connected to GÉANT2 via a separate connection.

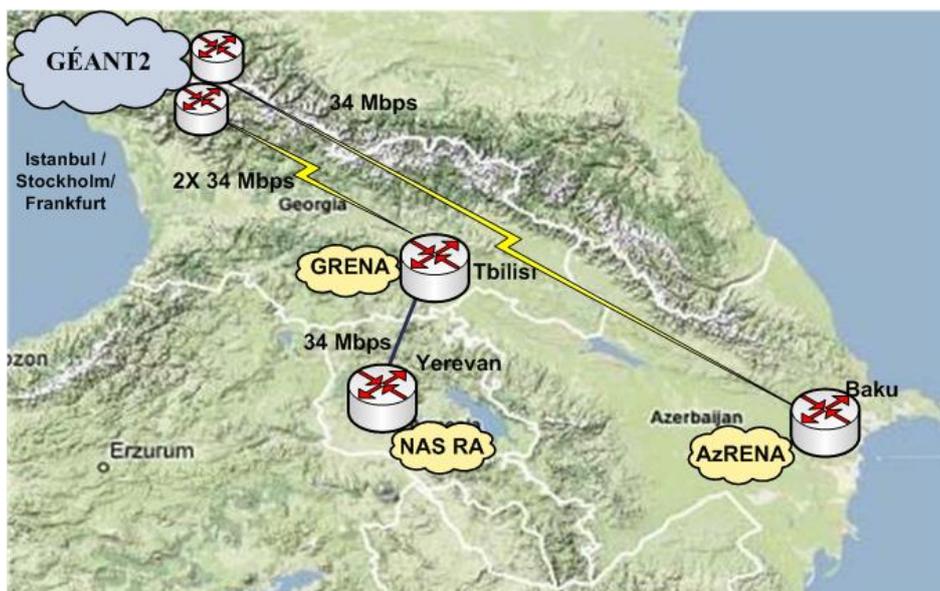


Figure. 5 Azerbaijan directly connected GÉANT2 and Armenia through Georgia

### 2.3.2. Hybrid Topology Option-II

In this topology, Georgia and Armenia are connected to each other and to GÉANT2 from Yerevan of Armenia, while Azerbaijan is connected to GÉANT2 via a separate connection.

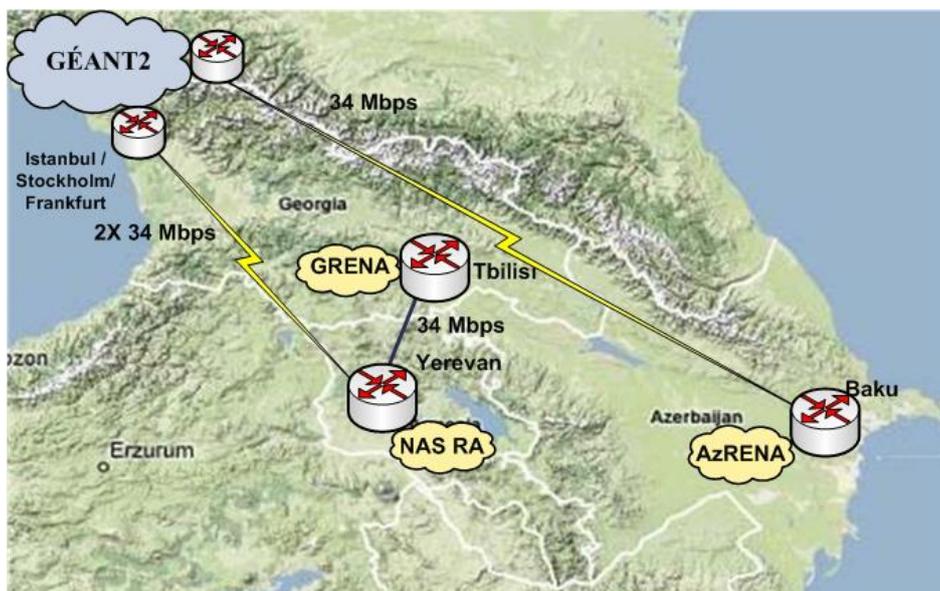


Figure. 6 Azerbaijan directly connected to GÉANT2 and Georgia through Armenia

### 2.3.3. Hybrid Topology Option-III

This topology assumes that Georgia and Azerbaijan are connected to each other and to GÉANT2 from Tbilisi of Georgia, while Armenia is connected to GÉANT2 via a separate connection.

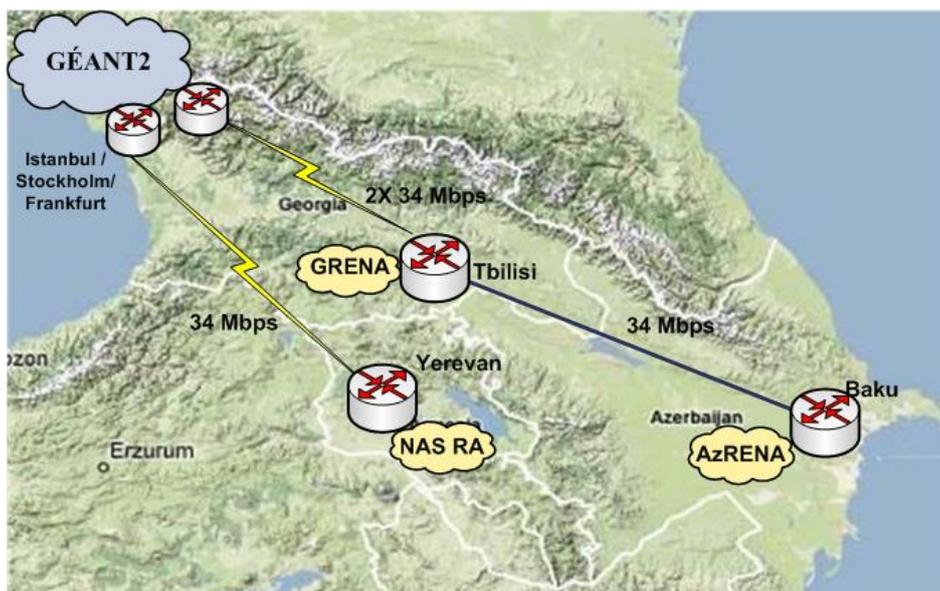


Figure. 7 Armenia directly connected to GÉANT2 and Azerbaijan through Georgia

### 2.3.4. Hybrid Topology Option-IV

This topology assumes that Georgia and Azerbaijan are connected to each other and to GÉANT2 from Baku of Azerbaijan, while Armenia is connected to GÉANT2 via a separate connection.

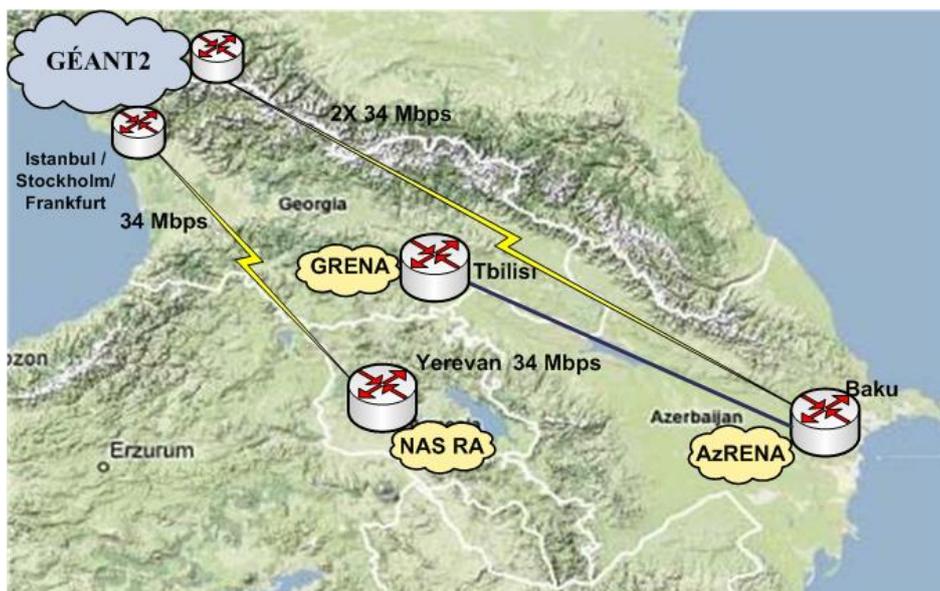


Figure. 8 Armenia directly connected to GÉANT2 and Georgia through Azerbaijan

### 3. Assessment of Topology Options

#### 3.1. Financial/Economical Assessment

Although the Porta Optica Study suggested in project deliverable D3.3v3 that the capacity of the connectivity to GÉANT2 should at least be 622 Mbps with an equal share of 155 Mbps per each country, the budgetary constraints of the BSI project are expected to limit the capacity of GÉANT2 connectivity to a value around 100 Mbps with an equal share of 34 Mbps for each country.

This assessment is based on the pricing information obtained from the Porta Optica Study which states that the price of leasing a capacity of 622 Mbps between Batumi-Istanbul and cost of interconnections between Georgia-Armenia and Georgia-Azerbaijan (155 Mbps or each) sums up to 7,310,000 € per year. There is also a special price offer of 4,161,000 € if all of these connections are provided from the same supplier. However, even the special price for 622 Mbps GÉANT2 connection with 155 Mbps per country is much higher than can be afforded by the BSI project.

Although all the scenarios in this deliverable are developed based on the minimum capacities, the actual capacities will be determined by the prices acquired from the tender and can be higher as long as the prices are affordable through the project budget.

From the financial point of view, the centralized topology options in general seem to be more attractive compared to decentralized or hybrid options which require more than one connection to GÉANT2 which is known to constitute the highest portion of connectivity costs.

When a comparison is made within the centralized topology options, the options which require more than 34 Mbps interconnection capacity between any pair of countries are expected to have higher costs if the cost of connection to GÉANT2 is not low enough to compensate the additional interconnectivity cost. When it comes to the cost of GÉANT2 connectivity, all South Caucasus countries seem to have connectivity options to GÉANT2 PoPs. However, because the connections from Armenia and Azerbaijan are provided over the Georgian fiberoptic infrastructure, or in partnership with Georgian providers, the connections from Georgia are expected to be the cheaper than the others at the result of the tender.

At this point, it might be useful to quote from Porta Optica Study that international connection of Georgia is provided via Turkey or Russia and prices for connection via Turkey are about 3 times lower compared to prices for connection via Russia (the price for 2 Mbps Internet connection is about 6500 € per month).

#### 3.2. Political Assessment

In addition to the fact that there is no fiber connectivity between Azerbaijan and Armenia, the opportunity of a direct interconnection between these countries is also not available due to political reasons. Regarding the potential conflict between two countries, the centralized topology options with Azerbaijan (Topology Option 2.1.3) or Armenia (Topology Option 2.1.2) as the center may not be preferable because the traffic of one country has to flow through the other's PoP while travelling to GÉANT2 in both of the topologies.

Although decentralized topology option and hybrid topology options both overcome such a potential problem, emphasizing the establishment of a regional network through centralized topologies can be beneficial for fostering the collaboration and communication between these countries.

#### 3.3. Technical and Managerial Assessment

The more number of routers and end-to-end circuits on the way to GÉANT2, the more points of failure and delay are introduced. From this point of view, decentralized topology option can be preferred to the others and topology options in section 3.1.2 and 3.1.3 seem to be the most disadvantageous ones. But it should also be

noted that the decentralized topology option eliminates the advantages of a regional network causing all the regional traffic to travel all through the GÉANT2 PoP.

On the other hand, centralized topologies can be preferable in the sense that they keep regional traffic within the regional network speeding the communication between South Caucasus countries and do not overburden GÉANT2 uplink with the regional traffic. However centralized topologies (especially the ones with Armenia or Azerbaijan as the center) are prone to more delay and potential circuit cuts due to the increased number of hops and circuits to GÉANT2.

Hybrid topologies have all the advantages and disadvantages discussed above depending on the composition of each topology.

### 3.4. Sustainability

Sustainability of the network will be assured by the VNOC created with the involvement of technical staff from the South Caucasus with the coordination of ULAKBIM. No matter which topology the tender results in, the operational support by VNOC will continue to sustain the stable operation of the network.

## 4. Conclusion

Deliverable D2.2 has presented the potential network topologies and analyzed the advantages and disadvantages of these topologies in order to prepare a base for the evaluation of tender offers.

Currently it seems that the best option to connect Southern Caucasus countries research networks to other NRENs through leased capacity instead of fiber leasing through a capacity of minimum 100 Mbps to GÉANT2 ensuring an equal share of 34 Mbps per each country. Despite some restrictions like unavailability of connectivity on some paths, there are several topology options that can be used to realize this network. According to the assessment of these topology options in terms of financial, political, technical/managerial and sustainability aspects:

- The centralized topology option with Georgia as the center seems to be the most financially attractive option without introducing any political risks. It can also be regarded as the best option for utilizing the advantages of a regional network.
- Although theoretically feasible, centralized topologies with Armenia or Azerbaijan as the center have many disadvantages such as the potential for political conflicts and technical merits like increased potential for circuit cuts and delays. If the tender does not result in superior prices for any one of these topologies, they are not expected to be the final topology for BSI.
- The greatest disadvantage of the decentralized topology is the high cost of international connections to/from the region. This topology option also does not make use of a regional network that is expected to reinforce communication and collaboration among the scientific communities in the region by the BSI consortium.
- Hybrid topologies may be expected to come up as a result of unexpectedly low international price figures for more than one country. They also do not totally fulfil the aspect of a regional network.

Of course, the final decision about the interconnections and the connectivity to GÉANT2 will be shaped according to the tender results. Therefore the assessments above should be regarded as guidelines for the tender evaluation but not as the final decision.