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DOI: <https://doi.org/10.1109/NOMSW.2010.5486575>

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ZORA URL: <https://doi.org/10.5167/uzh-33393>

Conference or Workshop Item

Accepted Version

Originally published at:

Hanemann, A; Hausheer, D; Reichl, P; Stiller, B; van Daalen, P (2010). Investigating the economic feasibility of bandwidth-on-demand services for the European research networks. In: 2010 IEEE Network Operations and Management Symposium - NOMS 2010, Osaka, Japan, 19 April 2010 - 23 April 2010. Institute of Electrical and Electronics Engineers, 201-204.

DOI: <https://doi.org/10.1109/NOMSW.2010.5486575>

Investigating the Economic Feasibility of Bandwidth-on-Demand Services for the European Research Networks

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Abstract—In the recent years, several technical solutions have been developed that allow Bandwidth-on-Demand services to be offered by service providers. In the context of the European academic networks, the technical feasibility of such services has been demonstrated on several occasions.

The move from a research activity to a production service presents further requirements in addition to the overcoming of technical challenges. Most notably, apart from organization of day-to-day operations, financial issues have to be solved. These relate to sharing the costs of a service that is delivered jointly by independent organizations. The main cost factors are operations staff as well as network resources that are purchased for on-demand use. Moreover, the financial issues also include pricing models for use of the service use as well as the distribution of the revenues among the participating organizations.

The present paper considers this fundamental BoD scenario together with key challenges in detail, before discussing the general approach for specifying a cost/pricing model.

I. INTRODUCTION

For many users of the Internet the transfer of data via IP is sufficient for the applications they run. However, for data-intensive applications it is highly desirable to circumvent transfer on the network layer in order to avoid packet loss or unforeseeable jitter behavior. It is therefore preferable to establish end-to-end (E2E) links over the backbone networks using technologies like native Ethernet, Ethernet over MPLS or SDH. For such an E2E link two main scenarios can be distinguished.

- In situations where high data volumes are permanent (i.e. are of, e.g., one to four years' duration) and where the paths of the flows are known and constant, it is sufficient to configure E2E links manually. An example of this situation are the E2E links that have been established for the connections of Tier0 and Tier1 centers in the optical private network for the Large Hadron Collider experiment at CERN [1].
- If high data volumes are only temporary (e.g. from a few hours up to a few months) and the paths for the flows are hard to predict, then a Bandwidth-on-Demand

(BoD) solution should be considered which means that E2E links are established automatically on demand. Such data-traffic characteristics are, e.g., found in the e-VLBI project [2].

In recent years the technical feasibility of BoD has been demonstrated on several occasions (e.g. [3]) and first deployments of such services are already realized by individual organizations (cf. Section III). However, economic issues related to BoD services have not been addressed in depth, particularly with regard to multi-domain cases where the service is offered jointly by independent organizations.

In this paper the scenario of the BoD service planned for the European academic networks is presented together with key economic research questions that relate to it (Section II). Based on these challenges the state-of-the-art is reviewed in Section III, in respect of both current services and research approaches. The proposed cost/pricing model approach for the European academic networks is then presented in Section IV. The last section concludes the paper with an outlook on current and future work.

II. BANDWIDTH-ON-DEMAND SCENARIO FOR THE EUROPEAN ACADEMIC NETWORKS

In Europe, there are National Research and Education Networks (NRENs) in each country which are interconnected by the GEANT network (the provider organization is called DANTE). Related to the evolution of the GEANT network, research and service activities have been undertaken in the GN2 project (2004 to 2009, [4]) and are continuing in the new GN3 project (2009 to 2013). In GN2/GN3, a software called AutoBAHN (“Automated Bandwidth Allocation across Heterogeneous Networks”, [5]) has been developed as a BoD solution that is interoperable with other software such as the DRAGON [6] and OSCARS [7] systems from Internet2/ESnet. For the system to work, all domains along a connection need to have a BoD software according to the joint interoperability protocol (Inter-Domain Controller Protocol) installed and

adapted to their local environment, and need to have resources ready for potential use.

While the development of the system has been a research activity in GN2, it has partially moved to a service activity, with the aim of becoming a fully operational service in the coming years. The plan is to develop a service definition until mid 2010 and for the service to be fully operational in five NRENs in Spring 2011.

In contrast to the situation in the US and Japan, it has to be taken into account that the service in Europe is going to be offered jointly by independent organizations. This situation is shown in Figure 1 for two example E2E links. Both links go from end-user site I1 to end-user site I2 (university or research institution). The first link uses resources in NREN1, NREN3 and in GEANT, while the second link is based on resources from NREN2 instead of GEANT. Such kinds of networking paths have become available with the introduction of cross-border fibers which directly link several NRENs. The situation in the example links can be regarded as a 1+1 protection of a networking path on the optical level.

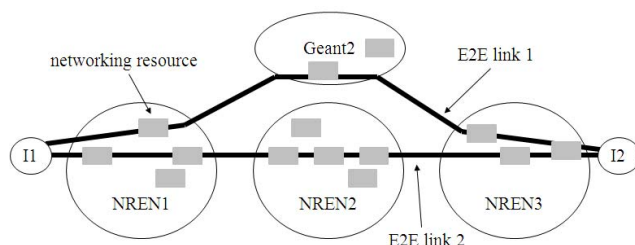


Fig. 1. BoD provisioning scenario in Europe

The figure does not show whether the network connections are static or dynamic. An end-user site should not receive a static connection to a GEANT network Point-of-Presence (PoP) to access BoD services that are then only provided by DANTE. Instead the aim is that, ultimately, all NRENs and DANTE participate in the service so that a dynamic path can be established directly at the demarcation point between NREN and end-user site and then to another end-user demarcation point potentially located in another country.

In terms of pricing and cost sharing the following issues have to be resolved.

End-site pricing: Due to the consumption of expensive resources when using the service it can definitely not be offered free of charge. Discussion on this point should focus more on a pricing model that is viable in the long term than on incentives to motivate early adopters of the service. Such a pricing model needs to show a benefit both for the providers who will invest in the new technology and for the users who will switch to the new service.

Revenue distribution: Due to the involvement of several organizations in the provisioning of a service, a distribution schema for the revenues that are received from end-users has to be agreed based on the resources that have been used for the service.

Cost sharing: Related to the distribution of revenues is the issue of cost sharing among the organizations. Each participating organization is taking a risk because resources have to be made available for on-demand use. The actual use of the service can be estimated only, which means that the costs may be only partly refunded by revenues.

Accounting: Based on the design of the pricing/cost model, a more or less sophisticated accounting system has to be designed and realized. As the effort for implementing and operating of the accounting system can be high, the accounting design should be considered in parallel with the design of the pricing/cost model.

III. RELATED WORK

Several existing networks offer BoD services already. The National Lambda Rail [8] in the US offers a dynamic VLAN service based on Ethernet using a user configuration tool called Sherpa. The pricing model for this service, specified in October 2009, forms part of the overall pricing model [9]. The cost for using the service is \$1.60 (or \$2 depending on member type) per hour per segment per 1 Gbps. A BoD service has also been introduced by the Japanese research network SINET (cf. [10], [11]). This BoD service is based on GMPLS Layer-1 paths and is mainly used to support data-intensive applications, e.g., remote backups or HDTV services. Using a web-based reservation interface, the user is able to select source and destination for the service, start and end time, as well as the requested bandwidth (in 150 Mbps intervals) and the route preference, e.g., if a route with minimal delay should be chosen. The amount of bandwidth made available for BoD services differs based on what remains from the daily Layer-2/Layer-3 traffic pattern. Currently, BoD services in SINET3 are allocated on a first come first served basis. However, a fair-admission control scheme is under study which has not yet been published. Internet2's Dynamic Circuit network [12] focused on three different fee models as part of their pilot service. Those models included a flat-fee model, a usage-based model, and a hybrid model combining flat fee and usage-based [13]. Finally, SURFnet would be able to offer a BoD service from a technology point of view (Nortel DRAC tool [14]). Their pricing model is currently based on monthly flat rates.

IV. COST AND PRICING MODEL INVESTIGATION

To address the challenges defined above, a collaboration has recently started between GN3 task JRA1 T3 ("Future Network" - "Federated Network Architectures"), Telecommunications Research Center Vienna, and the University of Zurich. The goal of this collaboration is to investigate the different options for a cost and pricing model for the European academic networks, as outlined in the following and summarized in Table I. Several scenarios for the selected options are being analyzed to determine whether it is likely that an economically viable BoD service can be deployed. This analysis will be used as a basis for selecting the options to make a proposal towards the decision-making bodies in the GEANT community (e.g. the NREN Policy Committee).

Service offer	DANTE only	DANTE and NRENs
End-site pricing	flat-rate or usage-based (for DANTE BoD service), flat-rate for NREN static service	flat-rate or usage based (or both, if no general policy)
Cost sharing	standard, every organization pays its costs	complex (static sharing or usage-based sharing necessary)
Revenue sharing	standard, every organization keeps revenues for its service	complex (static based on resources or usage-based distribution)
Accounting	relatively easy, independent solution in DANTE and NRENs (already existing in NRENs), complexity for DANTE depends on model chosen	quite complex, needs to be designed for multi-domain use, complexity depends on models chosen

TABLE I
OVERVIEW OF CHALLENGES ARISING FOR THE JOINT BoD OFFER BY DANTE AND NRENs

In front of the pricing and cost model discussion the service specification has to be fixed in details. This includes whether certain guarantees are given for the availability of the service. It can, *e.g.*, be possible that the service is unavailable because all resources within the backbone are used. In such a situation the end-user sites may get a penalty payment or it can be agreed that the service is delivered on a best effort basis only. Related to avoiding these situations it has to be decided how many resources are made available for the service.

A. End-site pricing

BoD services require the acquisition of expensive resources by providers (see Section IV-F). Since those acquisition costs have to be recovered, it is highly unlikely that BoD services can be offered free of charge except for certain test scenarios. It is also not possible that the whole service is regarded as a peer-to-peer service like in the GLIF collaboration [15] since the end-user sites do not share any own resources.

The simplest pricing solution would be a flat-rate model where an end-site has a certain access bandwidth (*e.g.* 2 Gbit/s) and is able to access any other end-user who also uses this service. A base unit (*e.g.* 1 Gbit/s) is defined and the user can establish connections up to the available access bandwidth, *e.g.*, in the current example two connections to two partner end-sites may be established with 1 Gbit/s each.

However, a flat-rate scheme may not be desired by the end-users, because if the bandwidth is not used, the flat-rate charge may be higher than a usage-based charge. The flat-rate scheme is also less efficient than a usage-based scheme, although it is often preferred by the end-users due to its simplicity and predictability.

Another option is a usage-based model, in which the bandwidth and duration of connections are taken as the basis for pricing, *e.g.*, the charge for x units of 1 Gbit/s used during y minutes would be x times y times c Euros.

A third option is a market-based model, where the charge depends on the current demand of the service as determined by

an auction, *e.g.*, during peak times with a high service demand the charge would be higher than during off-peak times. A variant of this model is the congestion-based scheme, where the service is only chargeable during times of congestion, but not otherwise.

B. BoD scenario options

There are two options for offering a BoD service within European academic networks. The first option is that only DANTE offers the service on top of the GEANT network. In this case, end-sites who wish to participate in the GEANT BoD service need to establish and pay for a static network connection with a fixed bandwidth (*e.g.* a wavelength or sub-wavelength) in their NREN to reach a GEANT PoP. This connection from the GEANT PoP onward can be switched in a flexible manner, in order to access another GEANT PoP and so reach another end-site linked to the service.

A more interesting BoD scenario in Europe involves not only the GEANT network as BoD provider, but also the NRENs. This means that an end-site selects a certain access bandwidth and can then reach in an on-demand manner any partner end-site that also has access to the service (and does currently not use a certain part of the local-access bit rate). In this way much more route options are made available which allow for better redundancy and shorter paths with lower delay.

C. Cost sharing

In the first scenario, DANTE has to consider how many and in which way resources must be allocated for BoD. This approach is not the best from a functionality point of view because the service is not as flexible as possible as just explained, but would alleviate the challenges with regard to cost and revenue sharing, even though operational issues still have to be coordinated.

The second BoD scenario, which involves the NRENs, is much more complex and requires research in terms of cost sharing. It is not clear how many and how resources must be allocated in the NRENs and DANTE, or by whom they are paid. Also, a single participating domain might harm the reputation of the overall service if it purchases only a few resources for the service and so often causes a bottleneck.

D. Revenue sharing

As with cost sharing, revenue sharing is simpler when the BoD service is offered by GEANT only. An end-user site is then a customer of both the NREN, for the static access service, and of GEANT, for the BoD service, and pays fees to both organizations accordingly.

In the case of a joint service offering, revenue sharing is more complex. The options are to distribute revenues based on the resources made available or related to resource use. While the latter option may seem more appropriate for allocating the resources properly (*i.e.* the organizations have a financial interest that they are actually used), path finding may then become a political issue. For example, a path from Germany to Italy can go via Switzerland or via the GEANT backbone.

In the case of reimbursement per resource use, the choice will determine whether the Swiss NREN will receive a revenue or not.

One way to address this issue would be to dissolve the role of collaborating NRENs and DANTE as peers, i.e. only DANTE offers the service, including within the NRENs. This means that DANTE acquires (lit) fibers and wavelengths from the NRENs and then offers the service directly to end-user institutions. The technical implementation would, however, still require the collaboration of the NRENs. In addition, it is not desired from a political point of view that NREN customers become DANTE customers.

E. Accounting

It is clear that the different options for service implementation and the cost/pricing models have implications for accounting. The modeling of the options therefore has to take into account which costs can be expected for implementing and running the necessary accounting mechanisms.

F. Scenarios modeling

For evaluating the options it is necessary to model certain input factors and to make assumptions about them. These points include the following:

- Details of service specification (in particular guarantees, penalties)
- Demand for service parameters (e.g. granularity of bandwidth chunks offered)
- Number of end-sites wanting to participate (related to the pricing selected)
- Service usage behavior of the end-sites (high use/low use per end-site, predictability of use)
- Service quality expectations of end-sites (tolerance of network bottlenecks, etc)
- Provisioning policy (degree of overprovisioning in the networks)
- Fiber costs (unlit or lit fibers)
- Transponder costs
- DWDM and switching devices' costs
- Energy, cooling, space rents, etc.
- Operations staff costs

Some of these resources are also used for other services. In particular, fibers are already in use for IP services, but in most cases several wavelengths are unused. In the cost calculation, there are three main options for handling this:

- The fibers are regarded as being already available without charge. This means that their costs are completely compensated by the IP services.
- The fiber costs are proportionally shared between the BoD services and IP services. E.g. if five wavelengths are used by the BoD services and 10 for the IP services, then the cost splitting ratio will be 5:10.
- If the aim is that the BoD service should be independent from IP services, the costs can be calculated so that they are fully compensated by the BoD service.

The cost-sharing issue applies not only to services but also to devices, energy, cooling and space rents as well as for operations staff. It is clear that the assignment of these costs can lead to quite different results in the calculation.

V. PRELIMINARY CONCLUSIONS AND FUTURE WORK

Finding a sound economic basis for the realization of BoD services is a challenging task, particularly when independent organizations need to collaborate to deliver the service. This paper has detailed these challenges and explained the possible options, together with the way they are going to be addressed. In the coming months, a project called ETICS is going to start, which will deal with related issues for the incumbent telecom carriers in Europe, showing that the challenges are not only relevant to the academic world.

The success of BoD depends not only on its technical feasibility and the cost/pricing issues discussed. It is also crucial that using the service for an application is so easy that the end-user is not aware of it.

ACKNOWLEDGMENT

Part of this research has been funded by (a) the Austrian Government and the City of Vienna within the competence center program COMET, (b) a fellowship of the Swiss National Science Foundation (Grant No. PA00P2_124152, EcoNets), and (c) the University of Zurich, Switzerland in the context of the COST Action IS0605.

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