# Planning of transmission infrastructure to support next generation BELNET network

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## Abstract

This paper describes possible scenarios for the transmission infrastructure supporting the next generation network of the Belgian NREN, BELNET. Also realistic estimations for future traffic demand are described. The evaluation of the scenarios includes a cost-based as well as a functional comparison, indicating how the required L1, L2 and L3 services can be provided over the considered network scenarios and what kind of network protection or restoration can be expected.

## Investigation of the problem

BELNET, the Belgian National Research and Education Network [1], supplies advanced internet services to Belgian universities, colleges, research centers and government services. The BELNET-network (GIGANET) was developed to promote research and training and to stimulate national and international scientific cooperation.

Today the national network consists of two star shaped structures, centralized in Brussels, from where data transmission lines of 2.5 Gbps depart to each of the national PoPs. BELNET makes use of managed SDH services for the transmission lines with on top an IP routing layer managed by BELNET. This model has proven its resiliency and cost efficiency but there are some new emerging technologies and bandwidth requirements which could make it more cost-efficient to change to a new model.

The considered study includes both the topology design (that should still connect all PoPs) as well as the choice of the appropriate underlying technology. In addition to the current IP (L3) connectivity, the next-generation BELNET network should be capable to provide a L2 and L1 service. The two BELNET core PoPs will be connected to the GEANT2 network (i.e. new network replacing the current pan-European research network, GEANT [2]) to provide an end-to-end L1 service and a L3 IP routing service. For this L1 service BELNET will be connected to an SDH DXC in the GEANT2 PoP via a number of wavelengths carrying STM-16/OC-48, STM-64/OC-192, GbE or 10 GbE signals. The switching granularity of this cross-connect is VC-4-Xc/v.

This paper elaborates on the considered network and demand scenarios as well as on suggested evaluation method used in the study.

## Specification of network scenarios

The economical interest of several possible future network scenarios for BELNET will be evaluated. Taking into account the presence of multiple telecommunication providers on the small Belgian surface, there is probably no need for BELNET to acquire all physical equipment itself. The following scenarios will be considered: BELNET builds a network on dark fiber (acquisition of own fiber, Indefeasible Right of Use (IRU) or leasing of fiber), BELNET builds a network based on leased wavelengths, BELNET leases a managed SDH network from an external provider or BELNET leases a managed Ethernet network from an external provider. A schematic overview of these scenarios is given in Figure 1.

| | Dark fiber | Wavelength network | SDH network | Ethernet network |
|---|---|---|---|---|
| L3 | IP infrastructure | | | MPLS network with VPLS sand L1 PWE support |
| L2 | MPLS infrastructure supporting VPLS | | | |
| | Ethernet infrastructure | | | |
| L1 | SDH DXC-based infrastructure | | | |
| | OXC wavelength infrastructure | | | |

**Figure 1 network scenarios**

Both the dark fiber and the wavelengths network are based on a wavelength infrastructure in core and access PoPs. In Figure 2, a schematic overview of the ownership of the equipment is given. In a dark fiber network, the multiplexers and the transponders are owned by BELNET, whereas in a leased wavelength network the external service provider owns this transmission equipment.

Figure 3 shows some important candidate configurations to implement the core PoPs. In the figure, we distinguish the fibers coming from the access PoPs and the fiber(s) to the other core PoP. We also distinguish a cross-connect (XC) that will be responsible for at least assembling the wavelengths to the GEANT2 network. This cross-connect will have direct access to all channels on the fibers from the access PoPs in the double star network configuration (parts b and d of Figure 3). In the other case (i.e., collector rings network configuration) (parts a, c and e of Figure 3) each collector will most probably feature an (O)ADM, because this is the most suitable type of equipment deployed in ring networks: the tributary ports of the (O)ADMs are then fed into the cross-connect, before being switched into the wavelengths to the GEANT2 network. However, as shown in part b and d of the figure, the rings might also be terminated directly on the cross-connect avoiding the installation of the intermediate (O)ADMs. Although this might require that the XCs feature for example self healing ring protocols. In Figure 3, a distinction is also made between the OTN and the SDH scenario. The major difference between these scenarios is that in the OTN case an OXC is used and in the SDH case a DXC. The DXC gives as a major advantage that it is possible to groom the traffic (pack low capacity traffic in high capacity streams). This is not possible with an OXC.

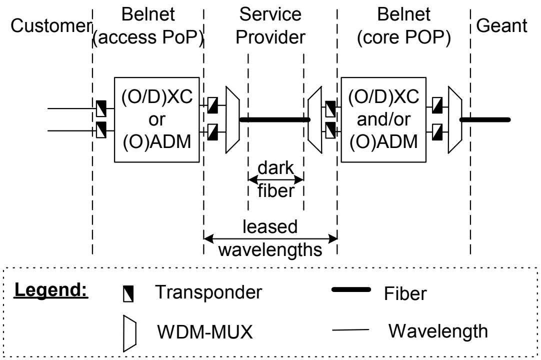


**Figure 2** **dark fiber versus leased wavelengths network scenarios**

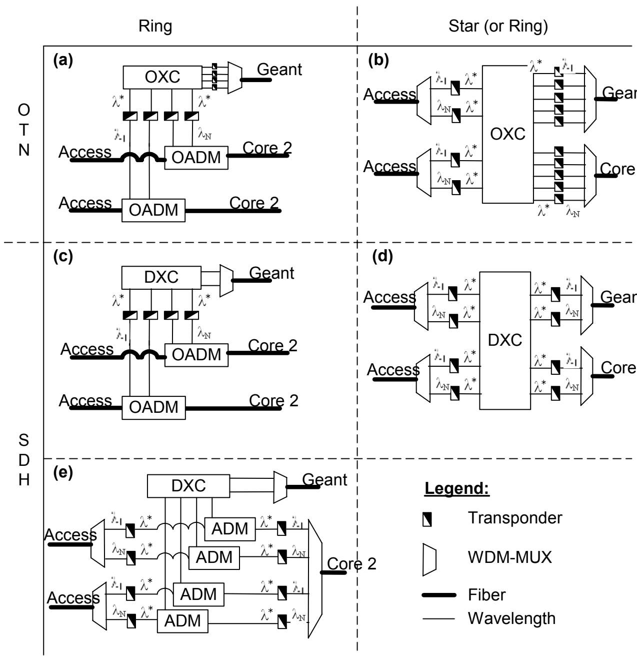


**Figure 3** **possible core PoP configurations**

Figure 4 shows four basic configurations for the possible configurations of the access PoPs. In those cases, the considered access PoP is connected to the two core PoPs. The two options on the top (a and b) are based on an OTN-network (not allowing grooming between different wavelengths). Options c and d are SDH-based, so that link capacity can be more efficiently used thanks to the use of traffic grooming on the sub-wavelength layer. Configurations a and c are more suitable for a ring topology, as (O)ADMs are designed to support ring protocols. The configuration b and d use (O/D)XCs and are therefore more suited to be used in a double star topology.

The configurations of Figure 4 could be extended to allow also the connection of an additional access PoP, which makes it possible to create a mesh topology. In cases where (O)ADMs are used, this means providing a back-to-back connection between the link from the additional access PoP and the link of one of the core PoPs. Where (O/D)XCs are used, the traffic from the additional access PoPs can directly be switched in the XC.

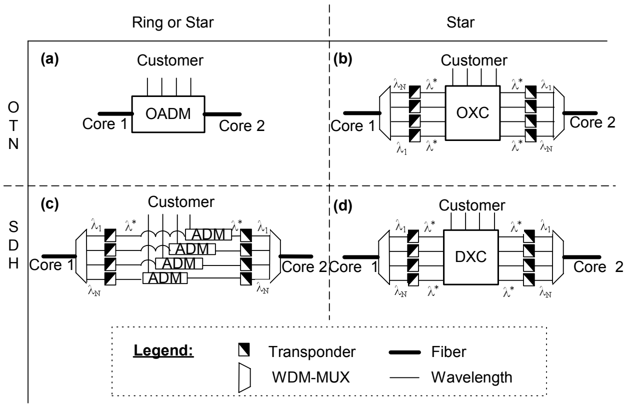


**Figure 4** **possible access PoP configurations**

| Core PoP \ Access PoP | DXC | ADM | OXC | OADM |
|---|---|---|---|---|
| **DXC** | VV | V (2) | VV | VV |
| **DXC+ADM** | X (1) | VV(1) | X (1) | X (1) |
| **DXC+OADM** | X (1) | X (1) | X (1) | VV (1) |
| **OXC** | VV | V (2) | VV | X (3) |
| **OXC+OADM** | X (1) | X (1) | X (1) | VV (1) |

**Figure 5** **combinations of access and core PoPs**

Dependent on the specific network topology, scenario and the cost of the capacity at the external supplier (dark fiber or leased wavelengths), we will evaluate whether or not grooming is beneficial in the different stages. For example, in case of a star topology it can be interesting to have grooming in the core PoP. Moreover, in Figure 5, an overview of the possible combinations of core and access PoP architectures is given. When an “X” is given this means that this option is not possible. In case of a “VV”, it is a good option and if a “V” is given it can be a good option but it is less obvious. Additional information for the entries in the table is given below:

(1) In cases were ADMs are used in the core PoPs, most likely a ring network is used, so that ADMs are also expected in the access PoPs. The same goes for OADMs in the core PoPs (and thus also in the access PoPs).

(2) Combinations of ADMs in the access PoPs and (O/D)XCs in the core PoPs are unlikely, as they can only be used in double star topologies. Moreover, using ADMs, grooming (statistical multiplexing) is only possible per wavelength (and not between wavelenghts).

(3) The combination of an OADM in the access PoP with an OXC in the core PoP is impossible. We assume the OXCs always to be surrounded by transponders, so that transparent switching is impossible, whereas on the other hand OADMs lead to transparent rings.

Apart from the possibilities to build an OTN or SDH network on top of dark fiber or leased wavelength infrastructure, the study also considers the option where BELNET leases some existing transport network infrastructure from an external provider. The impact on the provisioning of services by BELNET is described in the next section.

**Provisioning of services**

If BELNET leases a managed SDH network, all L1 switching infrastructure is provided by the external service provider. A schematic overview is given in Figure 6. As can be seen, a part of the cross-connect is reserved for BELNET, but the whole cross-connect has to be shared with several parties. The customers of BELNET can connect to the network using layer 1, 2 or 3. In case Ethernet traffic (L2) is sent over the SDH network, some line cards need to transform the signal using GFP/VCAT/LCAS. In this scenario there is no difference between the core and access PoPs.

Note that, when BELNET builds an OTN or SDH network on top of dark fiber or leased wavelength infrastructure (described in the previous section), the core and access PoPs are owned by BELNET instead of by the external provider. The provisioning of the services, using GFP/VCAT/LCAS for L2 traffic and an optional LSR for L3 traffic, is similar to what is described in Figure 6.

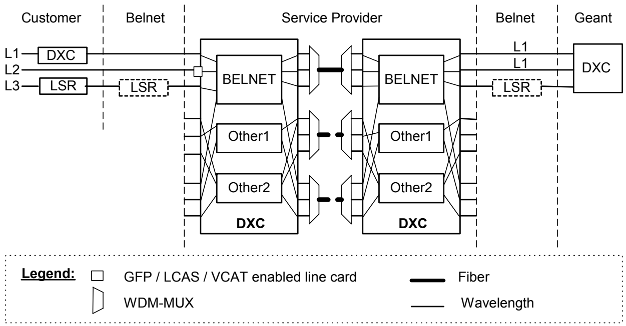


**Figure 6** **managed SDH network scenario**

In Figure 7 two options for the configuration of the scenario for a 10 GbE managed network are shown. In both options the network is owned by the external service provider. The difference between the two options is situated in the L2 and L3 equipment in the core and access PoPs. L1 traffic is sent into the LSR using L1 pseudo-wire emulation. In the uppermost option in the figure, a LSR is used which is not able to switch Ethernet packets. In this case a GbE-switch is needed to send the L2 traffic from the customer to the Ethernet network of the external service provider. In the bottommost option of the figure, the LSR is able to switch Ethernet traffic, so that the extra GbE-switch is not needed. In this case there is only the need of an extra line card to perform the L2 pseudo-wire emulation. As in the previous option, L1 pseudo-wire emulation is needed to send L1 traffic into the LSR.

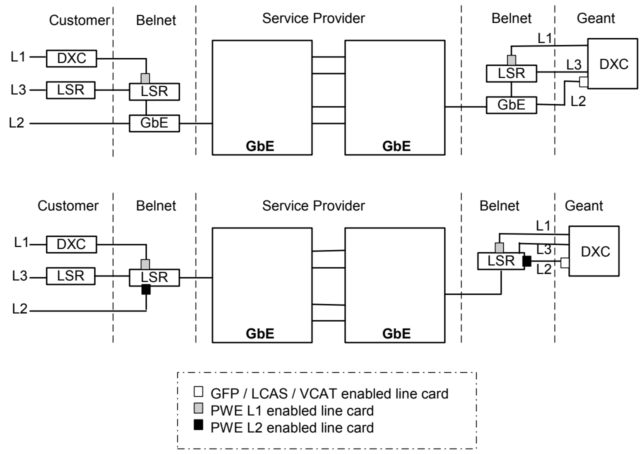


**Figure 7** **managed Eth network scenario**

**Specification of demand scenarios**

The PoPs in the BELNET network are divided in two groups: large and small PoPs. The large PoPs include the two core PoPs in Brussels. Figure 8 gives an overview of the considered demand scenarios for the two types of PoPs. The future IP traffic in all PoPs is expected not to exceed the capacity of two wavelengths, where we assume wavelengths of 10 Gbps for large PoPs and 2.5 Gbps for small PoPs. In all cases 1 wavelength is reserved for testing. In contrast to the current situation, the next-generation BELNET network will also offer L1 services. The future demand for these services is very difficult to estimate. For large PoPs we expect 1 wavelength will be needed for L1 services in all cases (100% of time), with a possible peak of 5 wavelengths for L1 services in 20% of the time. For small PoPs we expect no constant demand for L1 services (0 wavelengths for 100% of time) and a possible peak of 2 wavelengths for 20% of the time. A schematic overview of these demand scenarios as a function of GbE traffic is shown in Figure 9.

| PoP | probability in time | number of wavelengths for: | | |
|---|---|---|---|---|
| | | IP traffic | testing | L1 end-to-end service |
| large PoP | 100% | 2 | 1 | 1 |
| | 20% | 2 | 1 | 5 |
| small PoP | 100% | 2 | 1 | 0 |
| | 20% | 2 | 1 | 2 |

**Figure 8 demand scenarios**

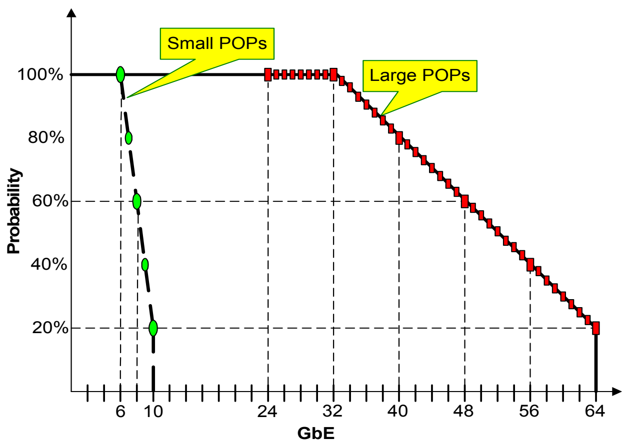


**Figure 9 demand scenarios, using GbE granularity**

**Identification of missing information**

Within the framework of the study, we developed a Request for Information to telecommunication providers active in Belgium, to solicit proposals from respondents who wish to work in partnership with BELNET to develop and deploy an Optical IP Network. The answers indicate that several providers indeed offer dark fiber and leased wavelength infrastructure, which would allow BELNET to build a flexible, high-capacity OTN or SDH based network on top of that.

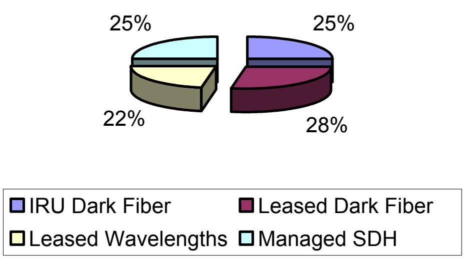


**Figure 10 Overview of offered scenarios**

In our opinion, the equal distribution of the different offered scenarios is very remarkable (see Figure 10).

Also a Request for Information to equipment vendors was written out to solicit solutions from vendors from whom BELNET can buy equipment to develop the Optical IP Network. The answers to this RFI will be used to determine the most suitable (functional as well as cost-effective) network scenario for a next generation BELNET infrastructure. As this data is very confidential, we can't give any more details about exact pricing information. The configurations that are suggested most correspond for the core PoPs with option (e) of Figure 3 and for the access PoPs with options (c) and (d) of Figure 4.

**Evaluation of the scenarios**

For all identified relevant scenarios for BELNET's next generation network, several cost evaluation steps will be performed.

1. *Link dimensioning*. Several scenarios will be evaluated, e.g. dark fiber versus leased wavelengths. This will include the study of grooming scenarios suitable in some of the network scenarios (grooming at core and/or access PoPs). Based on those evaluation results some scenarios will be selected and the suitable technology will be chosen.
2. *Node equipment dimensioning*. For the selected scenarios the entire network will be dimensioned (including the nodes), taken into account the equipment suggested by the vendors. The resulting total network cost will probably again lead to the exclusion of some of the scenarios.
3. *Cost break-down.* Based on the dimensioning results, a more detailed cost analysis will be made. Apart from the accurate costs specified by telcos and vendors in their answers to the RFIs, also suitable write off times will be taken into account. This analysis will lead to a cost break-down for all suitable scenarios. This will include both expected CapEx and OpEx costs [3] for several years into the future
4. *Investment decision criteria*. The relevant investment decision criteria (return on investment, payback time,...) will be calculated. This will allow to compare the total costs of all scenarios.

Based on the results provided by the cost analysis, together with the functional analysis (protection etc.), the final strategic decision for the next-generation network will be taken by BELNET.

**Indication about cost trends**

If we consider the results of the RFIs, we can make some cost considerations. In Figure 11 a comparison is made between the cost for SDH links and leased wavelengths. This cost is expressed in the cost per bit per km. You can see that the cost in the SDH case is more expensive than the leased wavelength case. Especially between a 10G wavelength and a 2.5G SDH link there is a big difference, the cost per bit per km of a 10G wavelength is in the range of one third of the cost per bit per km of a 2.5G SDH link. A 2.5G wavelength becomes cheaper only if a lease contract for 3 or more years is considered. SDH links of 10G were not taken into account because no data for such links was available. In the figure, the dark fiber scenario is not shown since the cost per bit per km is not straightforward to calculate. The total capacity of dark fiber depends on the equipment used. As a general number one can take 32*10G. The cost per bit per km for a dark fiber link is very low compared with this 320G of capacity. The cost per bit per km of wavelengths and SDH links are in the range of $10^{-6}$ while the cost per bit per km for dark fiber is in the range of $10^{-9}$. In the dark fiber case there is no linear relationship between the total cost and an extra wavelength. The basic cost is high, but the price for an extra wavelength is rather low.

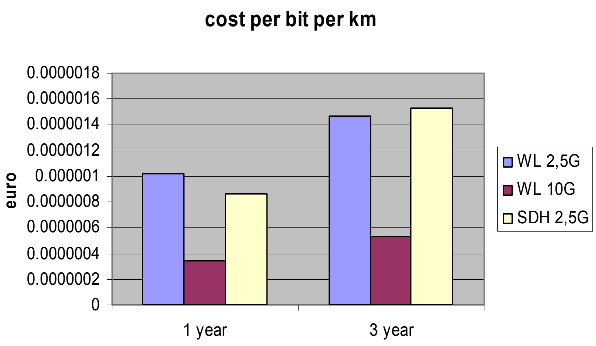


**Figure 11 cost comparison: SDH vs Wavelengths**

If we make some cost consideration with the dark fiber cases included, we better express the cost in cost per km per year. The costs of dark fiber (IRU and leased) and leased wavelengths are shown in Figure 12.

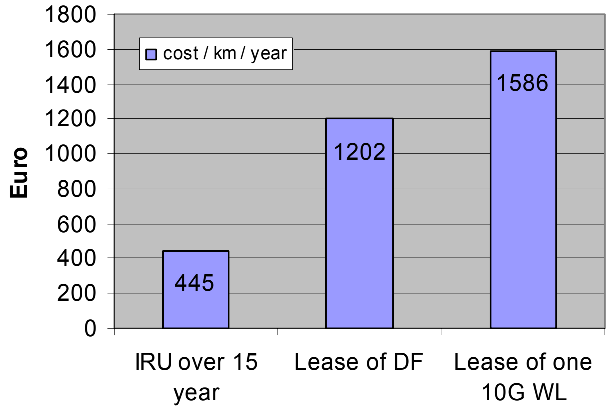


**Figure 12 cost comparison with dark fiber scenario included**

>From this figure follows that if the network infrastructure has to be acquired for a longer period an IRU on dark fiber will be cheapest. The biggest disadvantage of this scenario is that the total cost has to be paid in the first year. This can cause a shortage of budget in the first year.

It is also clear that leased wavelengths become very expensive if large traffic volumes are expected.

## Conclusions

This paper gives an overview of the possible options for a next generation transmission infrastructure to support the next generation BELNET network. Several network scenarios are considered: BELNET builds a network on dark fiber (acquisition of own fiber, IRU or leasing of fiber), BELNET builds a network based on leased wavelengths, BELNET leases a managed SDH network from an external provider or BELNET leases a managed Ethernet network from an external provider. First cost considerations indicate that an IRU on dark fiber for 15 years is the best choice in the long run. It is studied how the required L1, L2 and L3 services can be provided over the considered network scenarios. Attention is also given to the demand scenarios, indicating the expected future traffic.

## Acknowledgments

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## References

1. www.belnet.be
2. www.geant.net
3. S. Verbrugge et al., Operational Expenditures for Telecom Operators, Proceeding of 9th Conference on Optical Network Design and Modelling (ONDM2005), Milan (Italy), February 2005, pp. 455-466.