Network and Capacity Planning in SURFnet6

Ronald van der Pol[1] and Freek Dijkstra[1]

SARA Computing & Networking Services, Kruislaan 415, 1098 SJ Amsterdam,
The Netherlands
rvdp@sara.nl,Freek.Dijkstra@sara.nl
http://nrg.sara.nl/

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Abstract. SURFnet6, the national research network in the Netherlands [1], is a hybrid network that supports both static and dynamic lightpaths. By early 2009 there were more than 250 static lightpaths configured on the network. A dynamic lightpath pilot service started in December 2008. In order to understand the user requirements for lightpaths, we analysed current and historic data on lightpaths through SURFnet6. Understanding its behaviour allows us to make a conscious decision about where to add additional resources to the SURFnet6 network, and allows us to write path planning and monitoring software that is geared towards the actual needs of users and network engineers.

1 Introduction

SURFnet6 consists of around 7500 km of managed dark fiber in 5 rings through different parts of the Netherlands. DWDM is used on this fiber infrastructure. The DWDM equipment supports 72 different colours per fiber, but not all of them are in use on the network. Adding an unused colour to the network is one of the possible ways to increase the capacity of the network. On top of the DWDM layer a 10G SDH infrastructure is implemented. The SDH nodes are interconnected with 10G interfaces over the DWDM layer. Adding additional links between SDH nodes is another way to increase the capacity of the network.

SURFnet6 supports both static and dynamic lightpaths. Static lightpaths are manually configured by the NOC. Dynamic lightpaths can be setup by end users by using the DRAC web interface. DRAC [2] is Nortel's Dynamic Resource Allocation Controller, a dynamic lightpath reservation tool. For static lightpath planning a planning tool was developed [3]. The planning tool has knowledge of the topology of the network, the available resources and policies about the use of the resources. All information of used resources is stored in a database. DRAC is used for dynamic lightpaths. Part of the resources (e.g. timeslots on SDH links) are reserved for DRAC. DRAC can use this capacity for dynamic lightpaths.

The resources used by DRAC are stored in the same database as the resources used by static lightpaths, so that the database contains a complete view of the used resources.

In order to make the most optimal use of the network resources, new tools are being developed to analyse the current network usage. These tools are used to minimise the resource usage of currently configured lightpaths, to help decide where to add capacity and to decide the optimal amount of resources reserved for dynamic lightpaths.

The remainder of the paper is organized as follows. Section 2 measures the characteristics of lightpath based on historic data. Section 3 analyses the effect of replanning of lightpaths on the efficiency of the network. The article concludes with future work and conclusion in sections 4 and 5.

2 Characteristics of Lightpaths

By examining current and past network configuration, we can determine the characteristics of lightpaths in the SURFnet6 network.

2.1 Protection

SURFnet offers several classes of lightpaths: unprotected, protected and redundant (see figure 1).

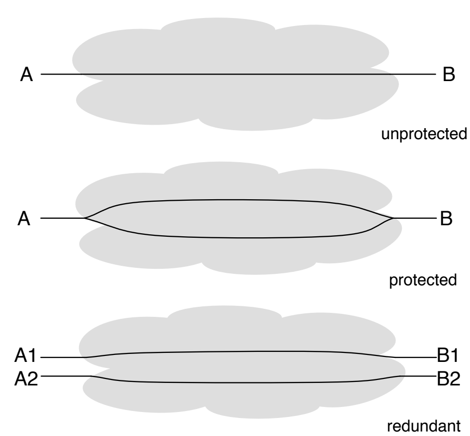


Fig. 1: SURFnet offers three classes of lightpaths: unprotected, protected, and redundant.

An unprotected lightpath consists of a single path between two endpoints. At each endpoint there is one user port. A protected lightpath consists of two diversely routed paths between two endpoints. At each endpoint there is one user port. The network switches to the working path in case of outages. A redundant lightpath consists of two diversely routed paths between two endpoints. The difference with a protected lightpath is that at each endpoint there are two user ports. The user needs to take care of switching to the working path in case of outages.

Furthermore, lightpaths can be part of an Optical Private Network (OPN). An OPN connects two or more sites with point-to-point lightpaths. Each lightpath can be protected, unprotected or redundant in any combination.

In April 2009, there were a total of 269 lightpaths configured in SURFnet6, of which 40 were unprotected, 88 were protected, and 141 were redundant lightpath circuits (here each circuit in a redundant lightpath was counted separately and there were five redundant lightpaths that consisted of three circuits). The complete overview of all lightpath circuits can be found in table 1.

2.2 Capacity

SURFnet offers lightpaths with a granularity of 1 VC4 (155 Mbit/s). Table 1 shows the capacities of currently configured lightpaths. 1 VC4 and 7 VC4 are the most popular, which corresponds to 155 Mbit/s and 1 Gbit/s circuits.

Type	1 VC4	2 VC4	3 VC4	4 VC4	5 VC4	6 VC4	7 VC4	64 VC4	Total
unprotected	8	1	0	0	0	0	31	0	40
protected	22	2	1	3	0	0	59	1	88
redundant	47	16	4	6	0	4	64	0	141
total	77	19	5	9	0	4	154	1	269

Table 1: The various lightpath classes in SURFnet6 as of April 2009

2.3 Duration of Lightpaths

SARA has managed the lightpaths through the SURFnet6 network since its inception in 2005. Between 2005 and 2007 these lightpaths were provisioned and maintained by hand. In 2006, SARA started working on an automated tool to find and monitor lightpaths, and took this tool in production in February 2007. Since the tool keeps historic records, we have a historic record of all lightpaths in the SURFnet6 network between February 2007 and present (see figure 2). This data gives us insight in the dynamicity of lightpaths.

One of our assumptions is that there are two categories of lightpaths: quickly changing lightpaths for single experiments and demonstrations, and more-or-less permanent lightpaths for production traffic. If our assumption is correct, we would see two peaks in lifetime of lightpaths: one for short-lived lightpaths and another for long-lived lightpaths.

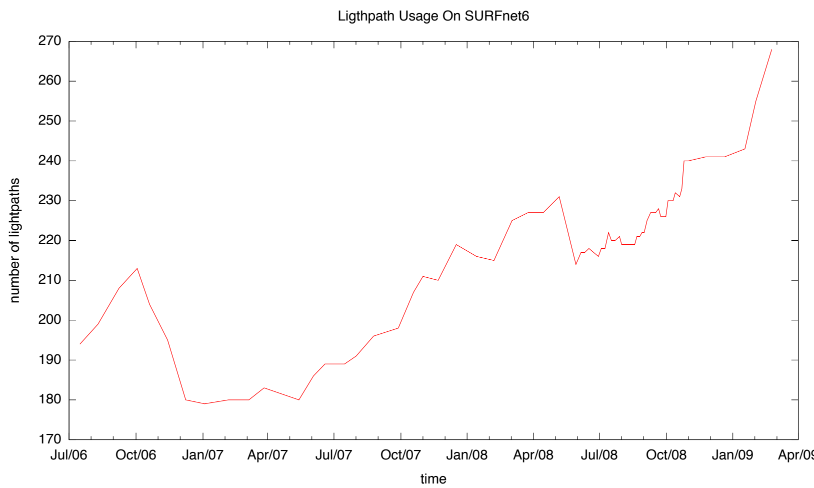


Fig. 2: Total number of SURFnet6 lightpaths over the years.

	raw data	corrected data
Decommissioned lightpaths	442	142
Still active lightpaths	271	257
Reserved lightpaths	23	22
Total	736	420

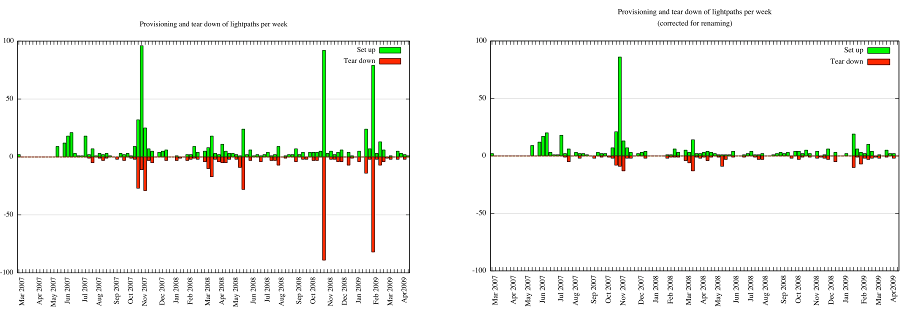
Table 2: The number of lightpaths in the SURFnet6 network between February 2007 and April 2009

Table 2 gives the number of lightpaths in the SURFnet6 network since February 2007[1].

When examining the raw data, we found a lot of occurrences where lightpaths would only exist for extremely short time, less then a hour. It turned out that in the a large fraction of these lightpaths were never used, but quickly thereafter replaced with another lightpath with similar characteristics. Another factor that influenced our data was the fact that lightpaths are identified by their name, but lightpath were renamed a few times. This is clear from figure 3a where there are two large spikes on 24 October 2008 and 4 February 2009, when we moved to a new naming schema. To compensate for this effect, we determined which lightpaths are equal, yielding the much less spiked figure 3b. An unfortunate side-effect is that multiple lightpaths in an optical private network (OPN) are now counted once.

Figure 4 displays the lifetime of both decommissioned as well as still active lightpaths. The large spike is caused by all ligthpaths that were first found in the

[1] The difference between 269 lightpaths in table 1 and 271 lightpaths in table 2 is caused by using a slightly different data set for both analysis.



(a) Raw data

(b) Corrected for renaming

Fig. 3: Set up and tear down of lightpaths over time

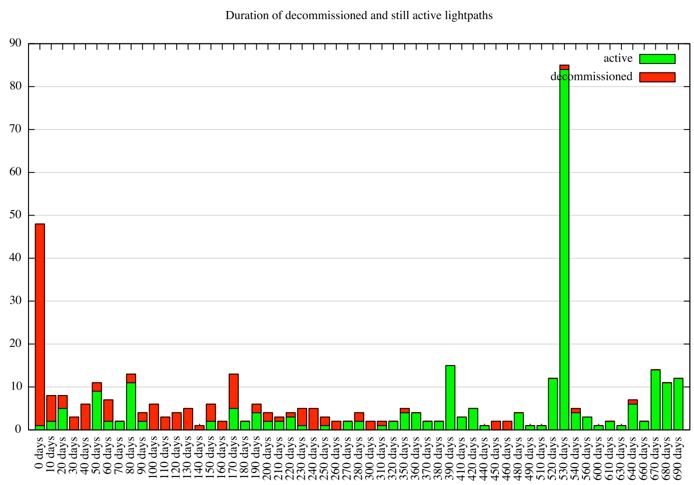


Fig. 4: Lifetime of lightpaths.

database on 26 October 2007, and remain in operation till today, which equals, 535,6 days. In reality, these lightpaths have existed before (as can been seen from figure 2), but were not found by the monitoring software. Despite these limitations in our data set, we can still draw the following conclusions.

– A significant number of lightpaths (140) have been active since the start of the data gathering and is still active. This is just over 50% of all active lightpaths or a third of all lightpaths ever. Apparently there is a long tail of lightpaths which remain in service for a long time. If we discount lightpaths that have existed for less then a day, then 52% of the lightpaths exist for over a year.

- Still a large number of lightpaths (48%) have been teared down after a year.
- If we look at the number of decommissioned lightpaths (so we do know their final lifetime), we do not see an exponential decrease. There seem to be a rather even distribution for lightpaths with a duration up to one year. This conflicts with our expectation of two spikes (one for short and one for long durations).
- The spike at 0-10 days is partly caused by lightpaths that only existed less then a day (24 lightpaths) and partly by lightpaths that existed between 1 and 9 days (another 24 lightpaths). This is still a significant number, apparently there is limited need for short-lived lightpaths.

3 Network Efficiency

With the help of the planning tool the currently configured static lightpaths can be analysed. The shortest path of a lightpath in an empty network can be calculated and can be compared with path of the actual configured lightpath. This gives insight in the difference between resources used in the optimal situation and what is actually configured in the network.

It is not possible to do an extensive replanning of all the lightpaths in all possible sequence orders to try to find the most optimal filling of the network. This would mean in the order of $n!$ path calculations, which is only feasible for very small values of n. But planning all lightpath on an empty network and adding all resources used gives insight in which parts of the network are the most heavily used.

Out of the 269 lightpaths (circuits) 168 were analysed with the planning tool. Not all circuits could be analysed because some features were not implemented in the tool yet. The total number of interfaces used by these 168 lightpaths was 1344, so on average each lightpath circuit uses 8 interfaces (or 4 network nodes).

This was done in two ways. One way was to take each lightpath out of the network one by one and replan it on the existing network. The other way was to replan all lightpaths in an empty network. This resulted in three lightpaths that could be routed through the network more efficiently (see tabel 3).

Lightpath	Current interfaces	Interfaces after reroute on existing network	Interfaces after reroute on empty network
2075LP	12	10	10
2112LP	13	11	11
2098LP	18	16	16

Table 3: Possible optimisations by rerouting lightpaths

A further 35 lightpaths could potentially be rerouted more efficiently, but they were part of OPNs or redundant lightpaths. These lightpaths need to be analysed more carefully with respect to the resilience requested by the users. Some lightpath do not take the shortest path because they must not share links or devices with other lightpaths.

All 168 lightpaths were also planned in an empty network and the resources (SDH timeslots on the interafaces) used by all the lightpaths were added. This resulted in hotspots in the network. On the most heavily used 10 Gbps interfaces 168 out of 192 timeslots were used. For the 2.5 Gbps interfaces, four out of the 97 interfaces needed more than the full capacity, indicating a network bottleneck on these four interfaces. The extra capacity needed was 63, 63, 54, and 54 timeslots out of the 48 available. Upgrading these links to 10 Gbps could be benificial because this would result in a network where all current lightpaths could be routed through the network optimally.

4 Future Work

The planning tool uses a topology description of the network. The Network Description Language (NDL) framework [4] of the University of Amsterdam is used for this. Links can be added to the topology description for places where adding additional bandwidth is considered. By replanning of the lightpaths, an analysis can me made of what the effect of the extra link would be.

Dynamic lightpaths have their own set of capacity management challenges. Reserving too many timeslots for DRAC wastes resources, but reserving too few timeslots will result in many failed attempts to setup a lightpath. Choosing just the right amount of timeslots is a new challenging activity.

The Erlang queueing theory probably does not work for dynamic lightpaths. E.g., the Erlang function only applies when the connection setup follows a Poisson distribution. When humans decide the starting time, they are more likely to choose 8:00 as a starting time than 8:09. Therefore, simulation is probably needed to get an understanding of dynamic lightpath resource requirements. This can also be done with the SURFnet6 planning tool by using only the resources reserved for DRAC. A connection setup and tear down pattern can be given as input to the planning tool and the number of failed attempts as a function of the time can be analysed.

5 Conclusion

The planning tool used for SURFnet6 turns out to be a very useful instrument to analyse the lightpaths in the network. Replanning of the lightpaths that were present in the network was useful to get insight in how many lightpaths could be routed more efficiently.

The characterisation of lightpaths has shown that has been a large need for lightpaths of 100 MBit/s and 1 Gbit/s, but not (yet) for 10 Gbit/s. There is a rather even distribution between short lived lightpaths ($<$ 10 days) (6%), moderated duration (10 days-1 year) (42%) and long duration ($>$ 1 year) (52%).

There is not a clear distinction between short-lived and long-lived lightpaths, as we expected.

Acknowledgements

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Rob Juffermans has authored most of the Java code, which was essential for the analysis in this paper.

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Vitae

Ronald van der Pol has been working in the field of Education and Research Networks for more than ten years. His former employers include SURFnet and NLnet Labs. At SURFnet he specialized on IPv6 and is co-author of several RFCs. In recent years his focus is on monitoring and performance measurements of optical networks. He holds masters degrees in both Physics and Computer Science.

Freek Dijkstra received his M.Sc. in applied physics from the Utrecht University in 2002, and will defend his Ph.D. thesis "Framework for Path Finding in Multi-Layer Transport Networks" at the University of Amsterdam in the week after TNC 2009. Freek is currently working on topology discovery and network description at SARA's High Performance Networking group.