# Milestone MJ1.2.3: White Paper – Alien Wave Services in the NREN Community

## The operational challenges of taking foreign waves into production

**Milestone MJ1.2.3**

| | |
|---|---|
| Grant Agreement No.: | 238875 |
| Activity: | JRA1 |
| Date: | 20-09-2013 |
| Version: | 1.0 |
| Task Item: | Task 2 |
| Target Audience: | NREN technical networking specialists |
| Dissemination Level: | PU (Public) |
| Document Code: | GN3-13-164 |
| **Authors:** | Rasmus Lund (NORDUnet), Rob Smets (SURFnet) |


The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7 2007–2013) under Grant Agreement No. 238875 (GÉANT).

# Table of Contents

# Table of Figures

# Table of Tables

# 1 Preface

The ongoing adoption of hybrid networking sparked the demand for cross-border fibre (CBF) Dense Wavelength-Division Multiplexed (DWDM) links between National Research and Education Networks (NRENs). In this context, the use of alien (or foreign) wavelengths via DWDM systems from different vendors is an appealing concept. An example of an alien wavelength is a DWDM wavelength that is established between a transmitter and a receiver and then transported over the DWDM system either of a different vendor or of the same vendor but in a different domain. In the case of a multi-domain alien wavelength, the alien wavelength is transported over multiple DWDM systems from different vendors, where no optical-to-electrical-to-optical (OEO) regeneration is used at the boundary between the two DWDM systems. This approach reduces the cost per wavelength by approximately 50% (for each domain) compared to a connection with regeneration. Furthermore, this approach offers a "greener" solution since the required power consumption of the alien wavelength is about 50% less than a comparable solution using regeneration. In terms of operation, it greatly simplifies the design of the intermediate Point of Presence (PoP) where the two DWDM systems interconnect, resulting in CAPEX and OPEX savings.

The use of alien wavelengths has five main attractions:

1. Direct connection of customer equipment to third-party DWDM equipment and elimination of expensive transponders at the transition between two DWDM systems.
2. Reduced power dissipation due to elimination of regeneration.
3. Faster time to service.
4. Extended network lifetime owing to support of different modulation formats.
5. Reduced cost.

However, there are a variety of challenges that complicate the application of alien wavelengths within multi-domain DWDM networks. The main challenges are:

- System performance validation.
- Operation, Administration, Maintenance and Provisioning (OAM&P).

# 2 Motivations

## 2.1 Drivers and Challenges

Looking towards the next-generation network, NRENs face the challenge of finding the right balance between innovative network functionality, scalability and cost. Although they are somewhat different from traditional telecom operators in terms of service delivery, they too are impacted by trends such as cloud computing, mobility and general traffic increase. Research networks will also need to support the collaborations and projects ongoing in GÉANT, the pan-European research and education community, while still being green-IT-aware, and cost-efficient. The operational aspect of managing an advanced data network, plus delivering state-of-the-art services with a limited resource operations centre, is a challenge that requires highly skilled operators and the constant pursuit of smarter and more innovative ways of working.

Given these motivations, and GÉANT's obligation towards the community to investigate possible opportunities for exchanging foreign wavelengths, initiatives were taken to experiment, consolidate, verify and test how foreign waves can be implemented as a network service in the NREN communities.

## 2.2 SURFnet and NORDUnet

SURFnet and NORDUnet have a history of significant partnership and strong relationships, and are habitually responsive to new ways of collaborating. Thus the concept of utilising the CBF between the two NRENs to support existing router connections, by carrying them as foreign wavelengths in the partner's domain, was appealing to both parties. Traditionally these circuits are leased or would require significant investment in equipment to carry them internally to each NREN, while existing infrastructure from the NREN partner could alleviate the work required to carry the traffic.

In particular, the idea was proposed of carrying some of SURFnet's router traffic from Amsterdam to Copenhagen via the infrastructure NORDUnet has from Hamburg to Copenhagen, and thus saving equipment and operational cost due to the transponder savings in Hamburg. Figure 2.1 below shows the principle of eliminating transponder sets in a multi domain DWDM setup.

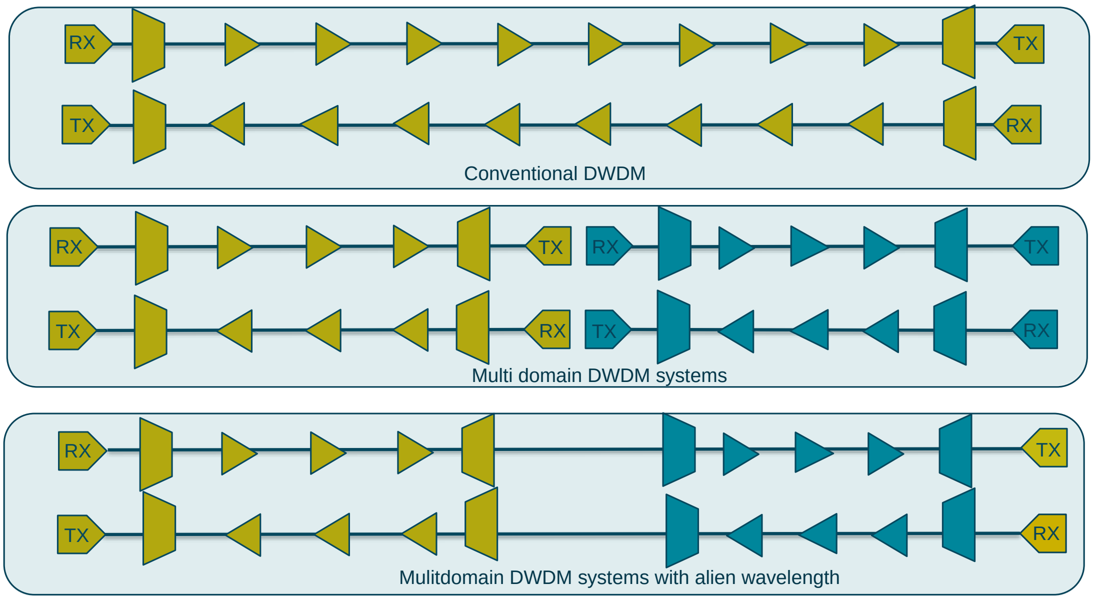



Figure 2.1: Alien wavelength transport service (bottom) compared to multi-domain (middle) and conventional (top) transport service

### 2.2.1 SURFnet

SURFnet operates a 12,000 km dense optical network in The Netherlands with over 400 Points of Presence. In addition, several cross-border fibres are operated, such as the optical link from Geneva to Amsterdam and between Hamburg and Amsterdam. The network is used to provide Layer 2 (L2) lightpath services on which IP services and other applications are offered to education and research organisations.

With regard to connecting other institutions or networks, SURFnet aims to do this at low cost, but without compromising the performance of the service or the experience of its customers. It is for this reason that SURFnet has a strong focus on innovation. Alien wavelength connectivity is a good example of low-cost innovation.

### 2.2.2 NORDUnet

NORDUnet operates a world-class Nordic and international network and infrastructure service for the Nordic research and educational community.

NORDUnet provides the Nordic backbone to the global infrastructure for research and education, thereby interconnecting the Nordic researchers and students to NRENs throughout Europe. NORDUnet monitors international network research activities and development projects and coordinates Nordic involvement in these projects.

# 3 Experimental Stage

## 3.1 Introduction

At the beginning of the alien wave experimental stage, SURFnet and NORDUnet conducted a study to verify the feasibility of implementing alien waves as a service in the research community. This was followed by a more detailed simulation, analysis and verification stage in which a total optical model was used to investigate the effects of self-phase modulation (SPM), cross-phase modulation (XPM), Optical Signal to Noise Ratio (OSNR), non-linearities and guard band variations.

The experimental stage consisted of several important steps:

- Feasibility study.
- Power-level estimations from a vendor simulation tool, verification of optical line of sight, and power-level monitoring.
- Offline simulation and optical modelling via a photonic modelling tool.
- Field-testing via built-in monitoring tools.
- Data comparison.
- Operational study.
- Reporting.

### 3.1.1 40 Gbit/s PM-QPSK without Regeneration

The first setup was to explore a 40 Gbit/s Polarisation Multiplexed-Quadrature Phase Shift Keying (PM-QPSK) wavelength traversing 1056 km between Amsterdam and Copenhagen, without regeneration, as shown in Figure 3.1.

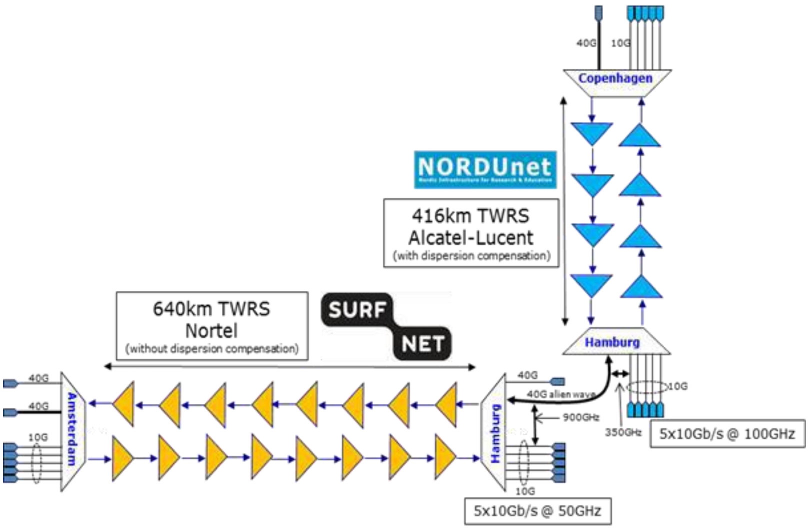



Figure 3.1: First implementation of the 40 Gbit/s PM-QPSK alien wavelength

The first 640 km, from Amsterdam to Hamburg, was carried through SURFnet's Ciena DWDM network, the Common Photonic Layer (CPL) system. The remaining 416 km was carried from Hamburg to Copenhagen via NORDUnet's Alcatel-Lucent DWDM platform, the 1626 Light Manager product (1626LM).

The 40 Gbps wavelength was injected into the live production network with a relatively large guard band of 350 GHz, and was (at that stage) proven to run with error-free transmission for 30 days at Bit Error Ratio (BER) < 9.6E-18.

Despite these good results, some differences between the simulated and the measured power values (using a Ciena simulation tool) led to further investigations on another setup.

### 3.1.2 40 Gbit/s PM-QPSK plus 2 x 10 Gbit/s OOK

This setup involved the use of more channels and reducing the guard band to identify some engineering guide rules. Therefore two 10 Gbit/s On/Off Keying (OOK) test wavelengths (one on each side) were injected in Hamburg and the spacing varied from 50 GHz to 150 GHz in order to evaluate the guard band size versus system performance, as shown in Figure 3.2.

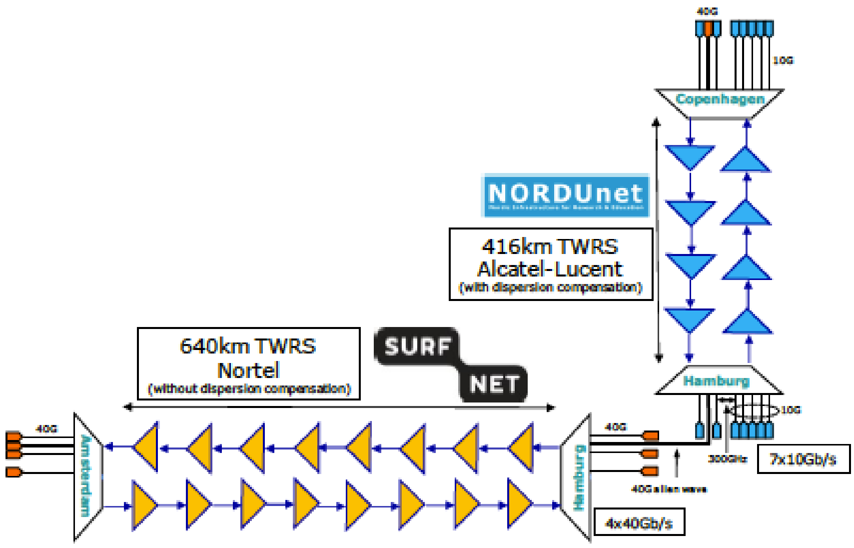



Figure 3.2: Revised version of the alien wavelength service

The power levels in this new setup were reduced to avoid fibre non-linear impairments. Table 3.1 shows the measured performance metrics of the alien wavelength in the new setup. BER performance was measured over a period of 15 weeks. Note that the error rate of $1 \cdot 10^{-37}$ represents the under-flow value of the Ciena reporting software.

| Location | $P_{TX}$ [dBm] | $P_{RX}$ [dBm] | $BER_{PRE-FEC}$ | $BER_{POST-FEC}$ | $PMD_{DGD\_}$ min/max [ps] |
|---|---|---|---|---|---|
| Amsterdam | 0.0 | -6.5 | $2.4 \cdot 10^{-4}$ | $< 1 \cdot 10^{-37}$ | 3/10 |
| Hamburg* | -7** | -8.0 | $5.1 \cdot 10^{-7}$*** | $< 1 \cdot 10^{-37}$*** | 2/8*** |
| Copenhagen | 0.0 | -9.9 | $4.4 \cdot 10^{-4}$ | $< 1 \cdot 10^{-37}$ | 3/11 |

Table 3.1: Link end-point performance data of the 40 Gbit/s optical terminations

**Key:**

* To and from the direction Copenhagen.

** Estimation based on measured Erbium Doped Fibre Amplifier (EDFA) output and insertion loss estimation of optical channel demultiplexer.

*** Determined by averaging measured BER and Polarisation Mode Dispersion (PMD) of the two direct neighbouring 40 Gbit/s signals that originate in Amsterdam but terminate in Hamburg.

## 3.2 Conclusions

### 3.2.1 Simulations

From the simulations that were performed to supplement the later testing, an investigation into which limiting factors were seen in the system was carried out. Parameters such as fibre non-linearity, PMD, noise and spectral cross talk effects were simulated and the conclusion was that it is mostly non-linearity factors that affect the transmission link.

It was also concluded that the solution could be to lower the optical launch powers along the link to minimise the non-linearity effects. This recommendation was applied to the second version of the alien wavelength implementation.

### 3.2.2 Testing

From the tests that have been performed it can be concluded that the link Amsterdam–Copenhagen using the alien wavelength between Hamburg and Copenhagen operated without transmission errors. In line with expectations, the pre-Forward Error Correction (FEC) error rate deteriorates when comparing reception in Copenhagen to the reception of neighbouring channels in Hamburg. This is due to additional transmission impairments caused by the Hamburg–Copenhagen system. PMD was not found to cause transmission impairments.

PMD values (expressed as Differential Group Delay (DGD) values) slightly increase between Hamburg and Copenhagen. This increase is also in line with expectations.

# 4 From Experimental to Production Stage

## 4.1 Introduction

The task of taking the experimental results, findings and recommendations from the alien wave project and applying them in a live production environment is complex and involves commitment from many parties. It is not just a matter of getting the technicalities in place, but also implies organised collaboration in order to define the correct procedures and agreements.

In principle, the alien wave should be handled in the respective Network Operations Centre (NOC), as for any other network service. Thus the rules of engagement should apply as usual, thereby reducing the probability of operational errors.

In reality, however, it becomes more complex because the provided service has reduced diagnostic and troubleshooting ability, and limited performance monitoring and fault isolation capabilities. Other issues worth mentioning are the lack of wavelength control, FEC interoperability, and lack of interoperability for service provisioning purposes.

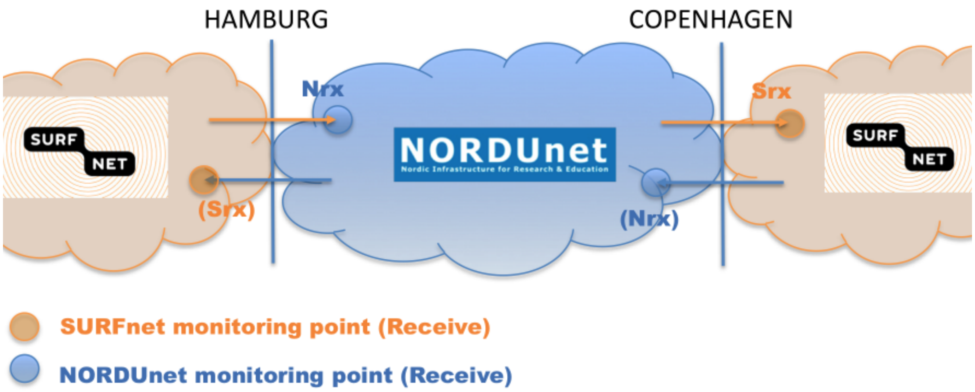
The only work within the standardisation sector of ITU-T that is related to alien wavelength support is found in recommendations G.698.1 and G.698.2 [G.698.1, G.698.2], which specify operational ranges for the interoperability of transponders for 2.5G/10G Non-Return to Zero (NRZ) signals for different applications.

Finally, the operational task and troubleshooting scenarios in a multi-domain environment are essentially more complex than in a single domain.

## 4.2 Responsibilities, Procedures and Acceptance Criteria

Given the complexity outlined above, the first step was to define reference agreements that identified the main tasks and clearly identified the responsible party. As a result, a responsibility matrix was created, to lay the foundation of the collaboration. Involving the different NOCs at this initial stage was a clear mandatory requirement.

An example of a responsibility agreement is shown in Figure 4.1.




- 2 Monitoring points, SURFnet -> NORDUnet **(Nrx)** and NORDUnet ->SURFnet **(Srx)**
- Both NREN's monitors their partners egress point. (the received signal from the partner
- All alarms and urgent matters will be addressed within xx Hours
- Upon urgent alarms situations below "Alarm situation" contact info must be used

| Tasks | Responsibility | |
|---|---|---|
| **Project partner** | NORDUnet | SURFnet |
| Monitoring point (S->N) | × | |
| Monitoring point (N->S) | | × |
| Informing about problem in (S->N) | × | |
| Informing about problem in (N->S) | | × |
| Keeping SURFnet spares for SURFnet in CPH. | × | |
| Replacing and reseating boards | × | |
| Documentation for onsite support | | × |
| Clear assignments for onsite support | | × |
| Spare part inventory tracking | | × |
| Ticket system information exchange | × | × |

| Partner | Contact info Alarm Situation | |
|---|---|---|
| | Telephone | Email address |
| NORDUnet | [redacted] | [redacted] |
| SURFnet | [redacted] | [redacted] |

| Partner | Contact info (Non urgent) | |
|---|---|---|
| | Telephone | Email address |
| NORDUnet | [redacted] | [redacted] |
| SURFnet | [redacted] | [redacted] |

Figure 4.1: Responsibility agreement sheet between NORDUnet and SURFnet

Later on in the project it was shown that procedures and processes are continuously evolving, with a tendency to change along with the general changes that are likely to occur in dynamic organisation environments.

Along with the development of the responsibility agreements, procedures and acceptance criteria were also created. for example, a procedure for contacting the NOC when site access is needed at Copenhagen, as this would potentially involve staff from NORDUnet to provide the operational access for some third-party company.

Figure 4.2 shows an example process diagram that illustrates how to arrange for local site access in Copenhagen.

| SERVICE | SLA |
|---|---|
| Site Access NON URGENT | **3 Business days** |
| Site Access URGENT | 2Hour |

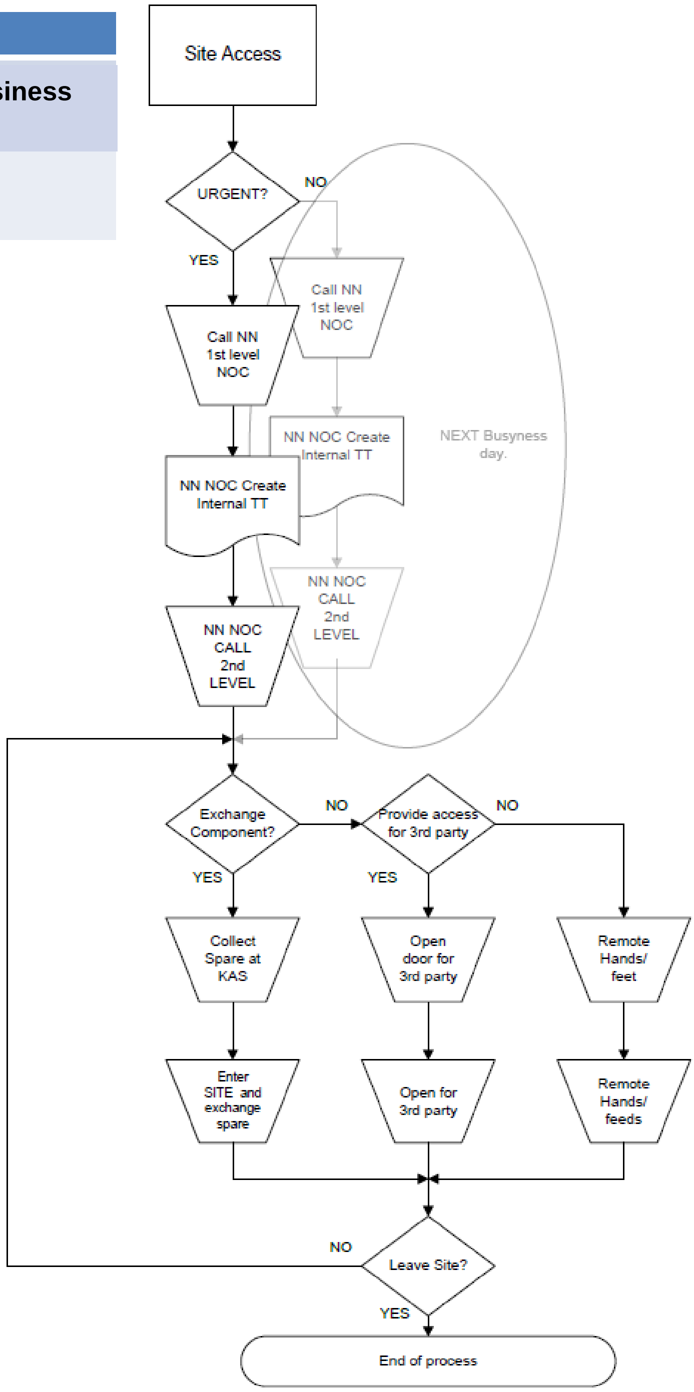



Figure 4.2: Process diagram for gaining site access in Copenhagen

The acceptance criteria were closely related to the documentation requirements of the different parties.

In NORDUnet, almost all documentation regarding procedures and processes are put on a protected web portal to centralise information. Furthermore, the operator can find information on all the cables, circuits, paths, ports, etc. of the entire NORDUnet network on this portal. This documentation system is called the Network Inventory and is a tool developed in-house.

SURFnet uses an integrated Inventory Management System (IMS) containing database engines and representation software. The tool allows retrieval of all the information needed to support procedures and processes as well as network topology information and service construction.

| Volgnr | Locatie | Node naam | Kaart poort |
|---|---|---|---|
| 1 | CPH001A | CPH001A_OME01 SHELF-1 | 2/0 (02)(EDC40G OCLD 1XOTU3+ DWDM CIRCUIT |
| 2 | | NORDUNET A-END | CPH001A-HB001A () |
| 3 | HB001A | NORDUNET Z-END | CPH001A-HB001A () |
| 4 | | HB001A_CPL01 | 9/7-8 (9)(SCMD8 GR5) |
| 5 | ASD001A | ASD001A_CPL12P-1 | 9/7-8 (9)(SCMD8 GR5) |
| 6 | | ASD001A_OME24 SHELF-1 | 2/0 (02)(EDC40G OCLD 1XOTU3+ DWDM CIRCUIT |
| | | | |

Table 4.1: IMS table of the alien-wavelength service between Amsterdam and Copenhagen

For example, Table 4.1 displays the service between the two Ciena 6500 systems, ASD001A_OME24 (Amsterdam) and CPH001A_OME01 (Copenhagen), which are the termination points for the alien wave. The NORDUnet's Alcatel-Lucent system is identified as NORDUNET A-END at location CPH001A (Copenhagen) and NORDUNET Z-END at location HB001A (Hamburg). CPH001A-HB001A is a dummy identifier for the equipment as this is outside SURFnet's domain.

In addition to IMS, SURFnet is migrating existing L0, L1, and L2 management, monitoring and control platforms to Ciena's proprietary OneControl system. A final objective of the migration to OneControl is to provide the NOC with a single-screen Operations Support System (OSS) tool. When the transition to OneControl has finished, two screens will display all management, control, monitoring and inventory information on services and infrastructure. Part of the migration to OneControl will be the implementation of alien wavelength monitoring functionality, which was initially planned for implementation on Zenoss [Zenoss].

## 4.3 Monitoring

During the alien wave experiments, different Operation, Administration, Maintenance and Provision (OAM&P) solutions were investigated. Most of the work done in the industry with respect to OAM&P did not seem to fully relate to the alien wave setup used in the project. Also, while the standardisation work in ITU-T that relates to alien wavelength seeks to specify the operational ranges for interoperability of transponders, this is only for 2.5G/10G NRZ signals and the standards specify a generic definition of an alien wavelength.

Industry literature suggests using a "test access point" for the Reconfigurable Optical Add/Drop Multiplexer (ROADM), where a copy of the alien wavelength is sent to an integrated monitoring device to monitor the signal. More sophisticated monitoring devices could, in principle, do chromatic dispersion and polarisation mode dispersion, but in order to provide a truly guaranteed transmission performance, digital access to the alien wavelength is required, which contradicts the general definition of an alien wavelength.

Another option is to have direct communication between the management planes of the different vendors via a custom-made proxy or to design a standard for information exchange. Such options have not been addressed in the standardisation bodies since the management plane implementation is a strictly proprietary matter.

Finally, having investigated the different options, it was decided to use the internal monitoring tools of each vendor and to start the monitoring work from there.

As the alien wavelength in this setup is only alien/foreign to the NORDUnet domain, the internal monitoring tools of Alcatel-Lucent were studied first.

### 4.3.1 Defining Monitoring Points

Looking at the add/drop side of the NORDUnet domain, the different options become clear (see Figure 4.3 and Table 4.2 below).

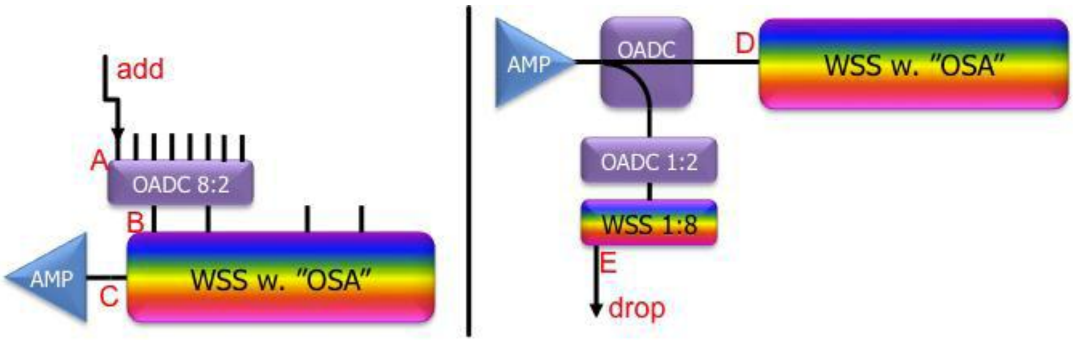


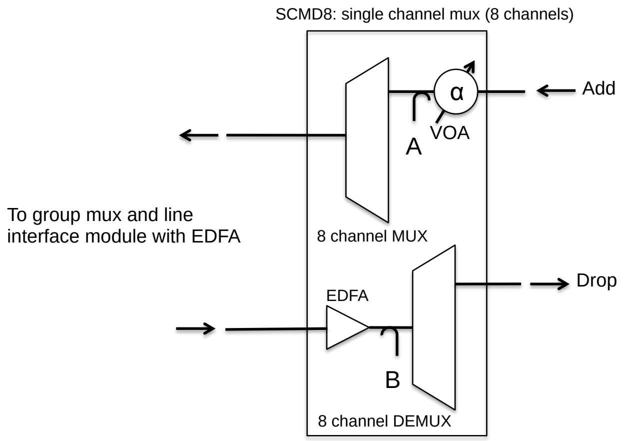

Figure 4.3: Monitoring points at add and drop locations on NORDUnet side in Hamburg

| Ref. | Component | Description |
|---|---|---|
| A | OADC 8:2 | Double 4:1 optical add/drop coupler with power monitoring |
| B, C, D | WSS w. OSA | Wavelength selective switch with ability to shut input ports (B) and measure and adjust power (C, D) |
| | AMP | Two-stage EDFA amplifier |
| | OADC | Passive optical add/drop coupler |
| E | WSS 1:8 | Tunable filter with ability to measure and adjust power |

Table 4.2: Monitoring ports

The monitoring ports shown above are all power monitoring points because the wave is a pure optical wave.

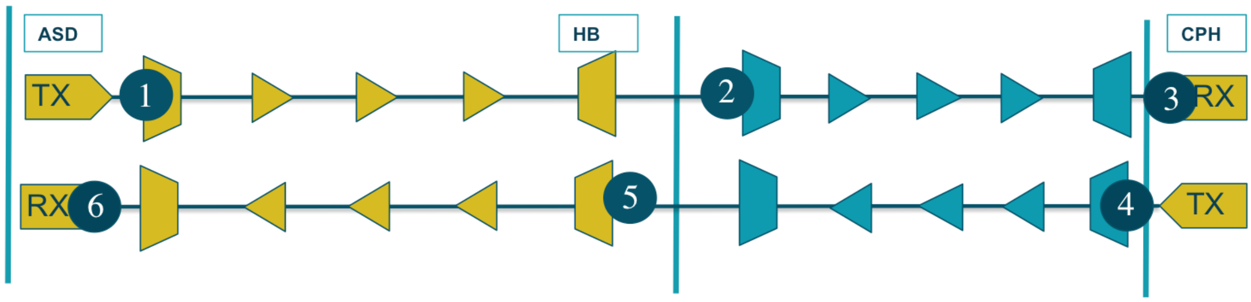
In addition to monitoring the received and transmitted power on the DWDM interfaces in Amsterdam and Copenhagen, SURFnet also monitors the power at the add/drop side of the SURFnet domain in Hamburg (Figure 4.4).




- Optical power monitoring point A on a SCMD8 measures channel input (Add) power.
- Optical power monitoring point B on a SCMD8 measures aggregate channel output (Drop) power.

Figure 4.4: Monitoring points at add and drop locations on SURFnet side in Hamburg

Add/drop monitoring in the NORDUnet domain gives information on the signal integrity on that side of the network only. It becomes more objective when looking at the full optical signal end to end. Figure 4.5 below shows the full signal propagation from Amsterdam to Copenhagen, and the different monitoring points identified along the way.




| Owner | SN | NN | SN | NN | SN | SN | |
|---|---|---|---|---|---|---|---|
| TP | 1 | 2 | 3 | 4 | 5 | 6 | Most probable cause |
| [redacted] | LOS | LOS | *LOS* | - | - | - | Asd Tx failure |
| | - | - | - | LOS | LOS | LOS | Cph Tx failure |
| | - | LOS | *LOS* | - | - | LOS | Asd-Hb fiberpair cut |
| | - | - | *LOS* | - | LOS | LOS | Hb-Cph fiberpair cut |
| | - | LOS | *LOS* | - | - | - | Amp failure Asd->Hb |
| | - | - | - | - | - | LOS | Amp failure Hb->Asd |
| | - | - | *LOS* | - | - | - | Amp failure Hb->Cph |
| | - | - | - | - | LOS | LOS | Amp failure Cph->Hb |

Figure 4.5: On-route monitoring points

As can be seen from Figure 4.5, there are 6 potential points that can lead to a “probable cause”, but the most interesting and obvious starting point would be monitoring points 2 and 5 as these are the handover points for the alien wave.

The monitoring work therefore started at these two points, and after implementation it was possible to track a Loss of Signal (LOS) in both domains. At a later stage, points 7 and 8 were monitored as well (Figure 4.6).

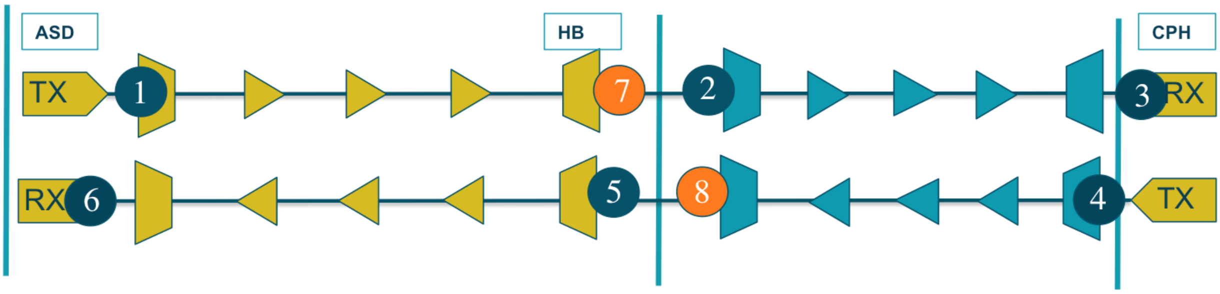



Figure 4.6: Added monitoring points for improved tracking of a LOS

### 4.3.2 Technical and Procedural Solutions

When monitoring connectivity, information is made available between domains and systems. This can be done in multiple ways, but a distinction can be made between two classes. One class is an implementation that relies mainly on automation and therefore requires technological resources; the other relies on the use of procedures and is often implemented using human resources.

As SURFnet is currently migrating to a new OSS, SURFnet's NOC preferred the second option. Motivated by the stability of the link and (yet) the limited number of alien wavelengths in cross-border fibres traversing multi-domains, it was decided to implement a procedure that is used when services over the alien wavelength fail or when alarms are triggered. Basically, it means that the table in Figure 4.5 is consulted when any loss of signal is observed and information is added as and when needed to draw a final conclusion. To this end the NORDUnet NOC has to be contacted. When the number of alien wavelengths is small and the links are reliable, this solution suffices. When more alien wavelengths are deployed, or when the alien wavelength service is not stable, automated monitoring is preferred. In such a scenario, operators must consider the coupling of the monitoring tool to the IMS system, to automate also the configuration of the monitoring tool, because cross-domain exchange of monitoring point information is often labour intensive and resource consuming.

NORDUnet's NOC uses a service-oriented, IT infrastructure monitoring system called Nagios®.

Nagios collects alarms from different elements in the network (ranging from, for example, cooling systems to router interfaces), and presents these alarms in a clear manner to the operator. As alarms are collected, the operator can investigate further in the individual systems that are generating the alarms.

The alarms associated with the alien wave from the Alcatel alarm system would therefore ideally be integrated into the Nagios monitoring system and thus NORDUnet decided to carry out this integration.

Figure 4.7 below shows the principle of how the Nagios system polls the alarm status from the Alcatel network management system (NMS).

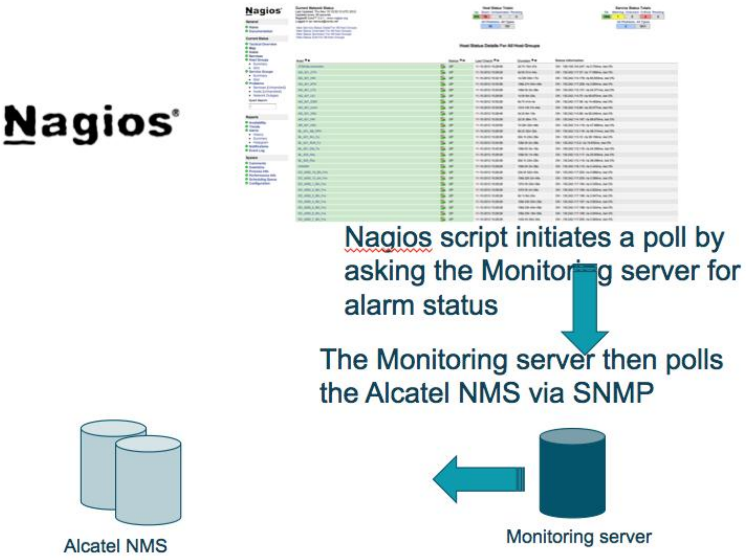



Figure 4.7: How Nagios polls the alarm status from the Alcatel NMS

A script was developed that, via a plug-in, initiates a poll in a monitoring server. The poll is then performed via Simple Network Management Protocol (SNMP) and the Alcatel NMS sends the actual alarm status back to the monitoring server. The monitoring server filters on specific ports and specific criteria before sending the status back to the Nagios system.

### 4.3.3 Testing

Three verification tests were performed to observe the response of SURFnet's and NORDUnet's NOC when failures on the link were emulated:

1. Laser failure in Amsterdam.
2. Laser failure in Copenhagen.
3. Signal failures in the NORDUnet domain.

#### 4.3.3.1 *Test 1: Laser Failure in Amsterdam*

**Objective**

The first test performed was to observe the alarms and verify the expected behaviour on the identified monitoring points when signal failure is simulated in Amsterdam.

### Setup

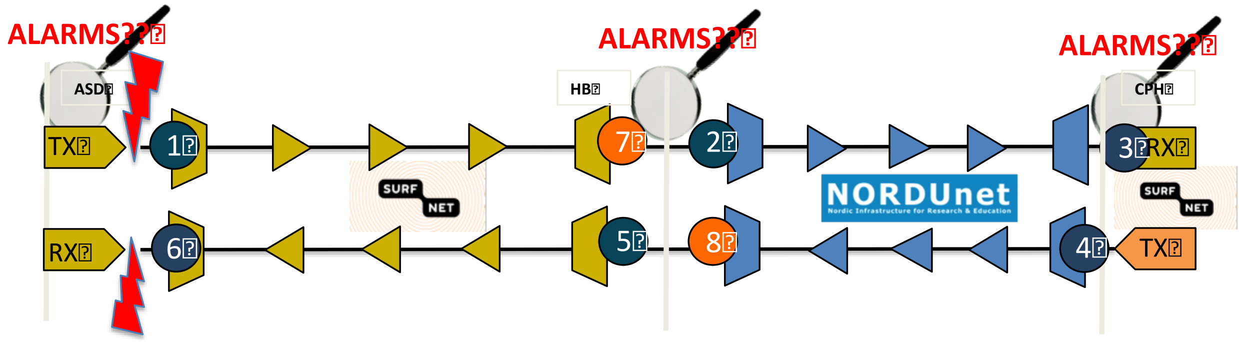



Figure 4.8: Test 1: Laser failure in Amsterdam

To simulate TX failure in Amsterdam, the wavelength was de-tuned and the card was placed out of service. The resulting alarms were documented via screenshots.

### NORDUnet Domain

**Expected Behaviour (Physical Layer Only)**

In the NORDUnet domain (at Hamburg), the expected behaviour was that alarms would occur at the “add” point of the alien wave in the Alcatel system (see Section 4.3.1 point “A”). As described in Section 4.3.1, this point is a passive coupler leading the alien channel to a Wavelength Selective Switch (WSS) component for further control in the total spectrum. Therefore the signal failure is expected to give alarms on this coupler.

As signal distribution fails from this point on, the expected behaviour was also that alarms would occur at the drop side in Copenhagen. The drop side is essentially another WSS component with 8 ports that drops the alien wave on one of these ports (point “E” in Section 4.3.1). Therefore alarms on the ports carrying the alien wave (AW) channel are expected.

Finally, alarms should appear both in the centralised alarm system, Nagios, and in the Alcatel network management system.

Results from the test were documented for both systems.

**Test Results: Alcatel**

Figure 4.9 shows a screenshot of the Alcatel network management system.

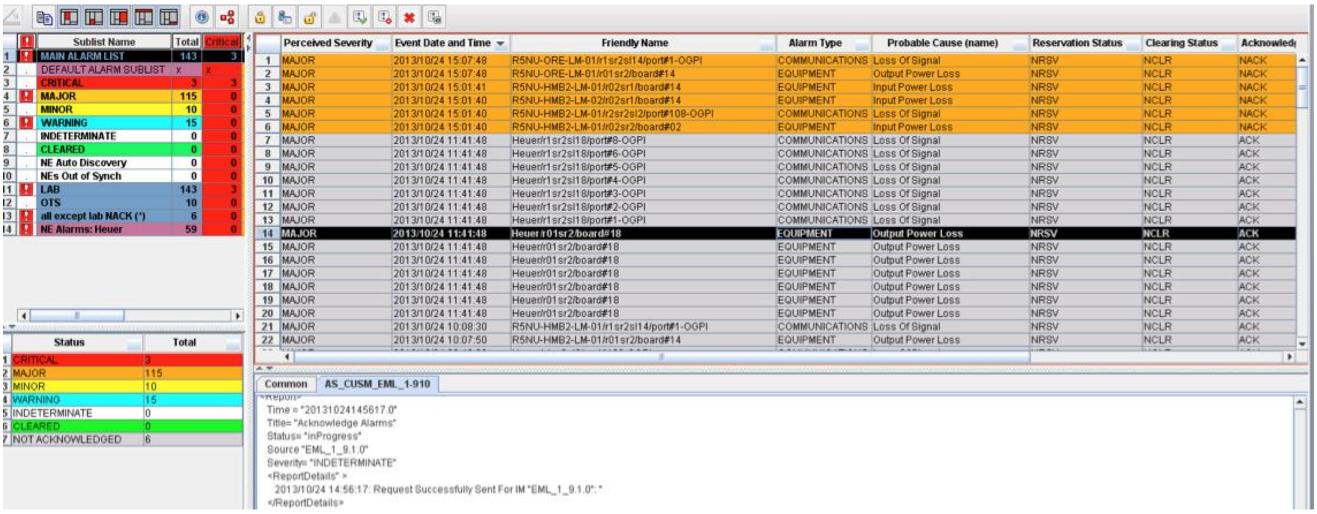



Figure 4.9: Screenshot of the response of the Alcatel NMS to laser failure in Amsterdam

The six red (orange) alarms from HMB (Hamburg) and ORE (Ørestaden Copenhagen) at the top of the screen show exactly the behaviour expected. The last two (numbered 5 and 6) are the previously mentioned coupler alarms in the “add” direction, showing that there is “Loss Of Signal” and “Input Power Loss” respectively at that port.

The two at the top of the list (numbered 1 and 2) from ORE (Ørestaden Copenhagen) are the alarms expected from the WSS component on the drop side, specifically showing “Loss Of Signal” and “Output Power Loss”.

The Alcatel system associates two alarms with one instance. One reports the equipment alarm (e.g. “Input Power Loss”), and the other reports the communication alarm (e.g. “Loss Of Signal”), but they are really referring back to the same reason: signal failure in Hamburg or Copenhagen.

**Test Results: Nagios**

Initially, there were some problems in getting the alarms in the Nagios system. Later it was found that, as a result of human error, Nagios was polling the wrong points and hence the alarms were not detected.

The script was corrected, and the test was performed again. This time the alarms were detected as intended, as shown in Figure 4.10.

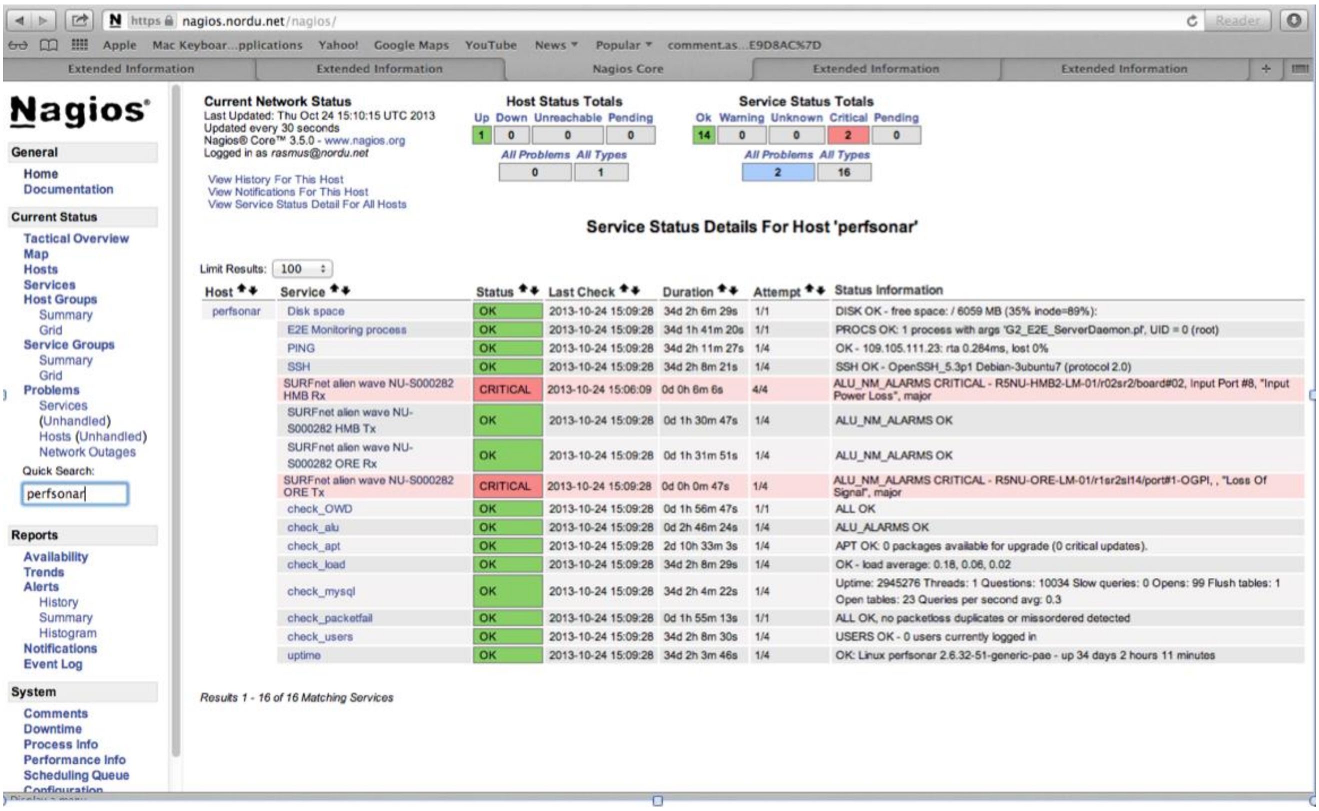



Figure 4.10: Screenshot of Nagios showing alarms caused by laser failure in Amsterdam

The alien wave service is seen from rows 5–8 in the table (Service ID NU-S000282). The two alarms marked in red are exactly the "add" and "drop" side of the service.

Row 5 is called "HMB Rx". This is the "add" side (the point where NORDUnet receives the alien wave) and that is exactly the coupler that is giving alarms in the Alcatel system.

Row 8 is called "ORE Tx". This is the "drop" side in Copenhagen, i.e. the WSS component as described above.

As these are the exact points expected to give alarms, the test validates the setup.

## SURFnet Domain

### Expected Behaviour (Physical Layer Only)

It was expected that the CPL equipment would generate an alarm because the optical signal does not reach the input of the optical multiplexer. In addition, failure on the link causes the 6500 system in Copenhagen to become unreachable over the in-band management system, while out-of-band management should still work. In addition to this alarm, alarms should also be generated by the 6500 system in Copenhagen. These alarms should not automatically appear as in-band management has become disrupted. Hence the status of the 6500 in Copenhagen should become unknown.

### Test Results

In the SURFnet domain, alarms showed up on the 6500 and CPL equipment (Figure 4.11). The bottom part of the figure shows the link, where the green line represents the link from Amsterdam to Hamburg, carrying several 40 Gbit/s connections, of which one becomes the alien wavelength between Hamburg and Copenhagen, indicated by the vertical red line. The blue lines are internal connections between CPL and the 6500. The 6500 system in Copenhagen appears as a blue question mark, as this box is not connected via in-band management. The top of the screen shows the Loss of Signal alarm occurring at the Variable Optical Amplifier (VOA) of the MUX in Amsterdam. No other alarms are visible.

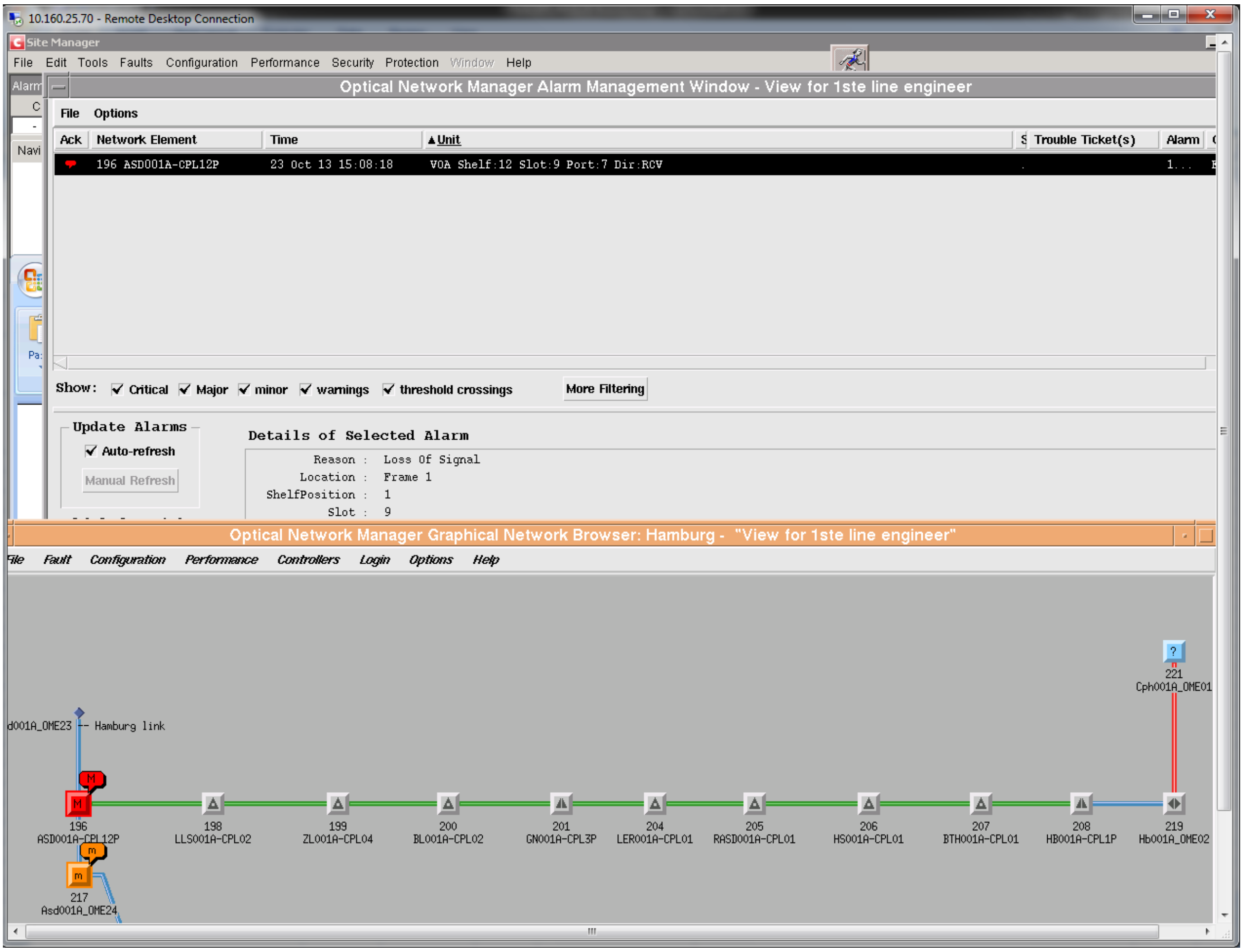



Figure 4.11: Alarms occurring due to laser failure emulation in Amsterdam

Figure 4.12 confirms the loss of in-band management connectivity, while out-of-band connectivity remains possible. Via out-of-band management the status of the 6500 in Copenhagen is retrieved and displayed in Figure 4.13. This screen confirms the expected LoS in Copenhagen and the raised critical alarms.


Figure 4.12: In-band management connectivity has become disrupted (right side); out-of-band management connectivity (left side) remains possible

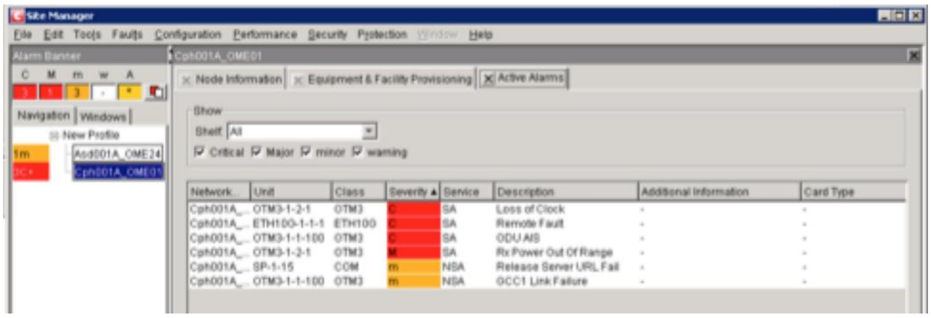



Figure 4.13: Critical alarms from the 6500 in Copenhagen are retrieved using site manager via out-of-band management

### 4.3.3.2 *Test 2: Laser Failure in Copenhagen*

#### Setup

Test 2 was the same as Test 1, except for the fact that SURFnet executed the transmit signal failure in Copenhagen instead of Amsterdam. Similarly to Amsterdam for Test 1, the Copenhagen wavelength was de-tuned and the card was placed out of service. The resulting alarms were documented via screenshots.

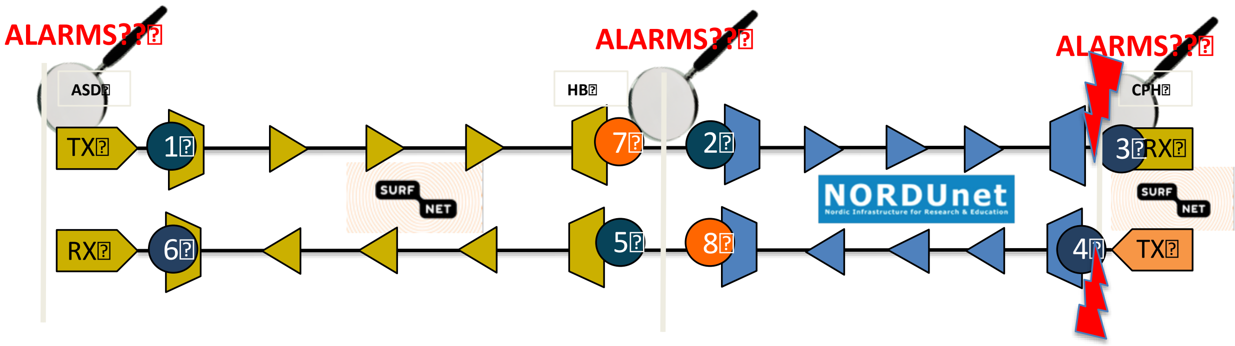



Figure 4.14: Test 2: Laser failure in Amsterdam

## NORDUnet Domain

### Expected Behaviour (Physical Layer Only)

As the test was basically the same as Test 1 (just seen from the other end), NORDUnet expected to see the same behaviour: the same alarms from the “add” point in Copenhagen and the “drop” point in Hamburg.

### Test Results: Alcatel

Figure 4.15 shows the screenshot taken for Test 2.

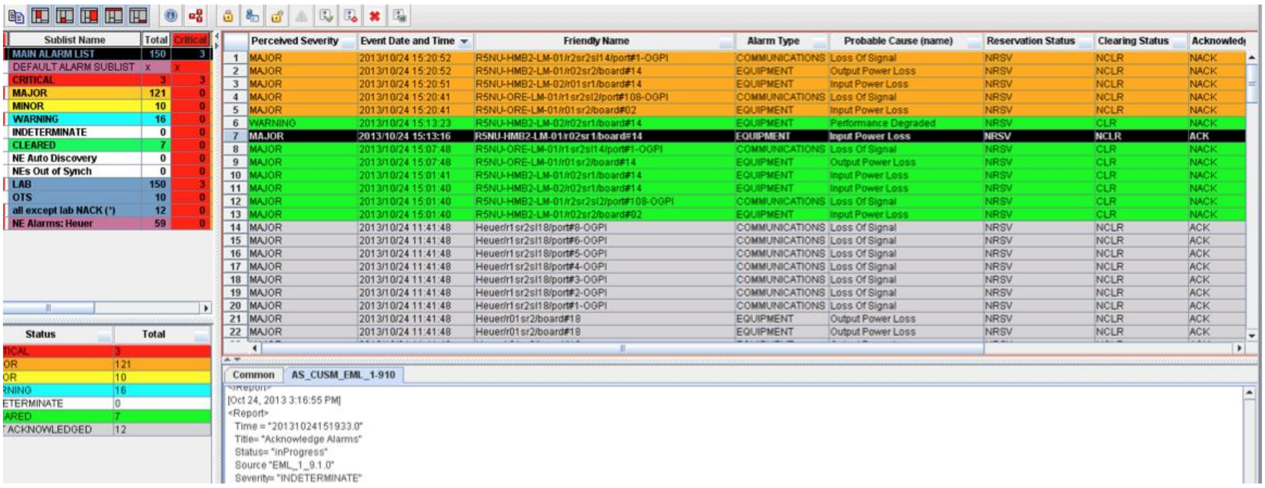


Figure 4.15: Screenshot of the response of the Alcatel NMS to laser failure in Copenhagen

### Test Results: Nagios

Unfortunately there seemed still to be some small corrections needed in the Nagios script, as one alarm was not reported.

The “ORE Rx” alarm was not detected in Nagios. However, performing a manual SNMP poll of the Alcatel servers, the error was found to be some problem in the Nagios script, as the Alcatel NMS did reply correctly to the SNMP poll (the “add” alarm on the coupler in ORE was reported).

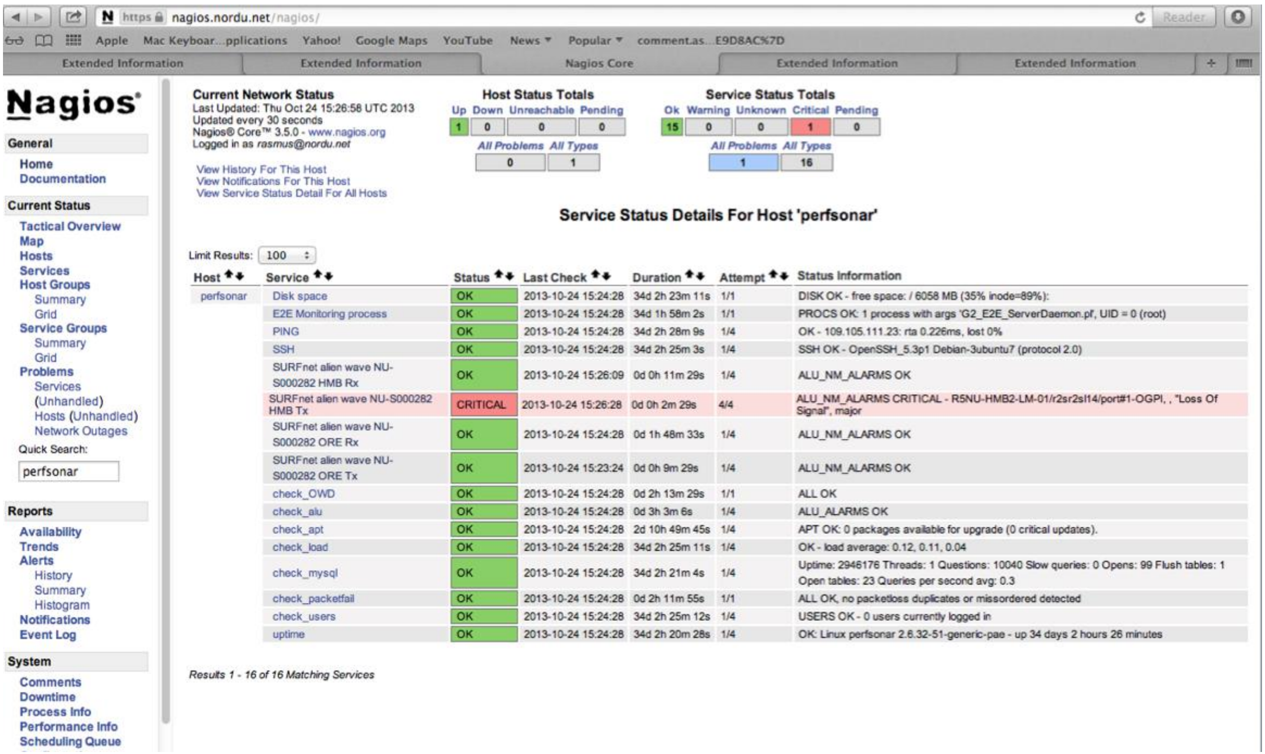



Figure 4.16: Screenshot of Nagios showing alarms caused by laser failure in Copenhagen

Apart from this problem, the behaviour was as expected and the bug in the script is regarded as trivial and easy to fix.

## SURFnet Domain

### Expected Behaviour (Physical Layer Only)

The expected behaviour was that line card failure in Copenhagen would cause alarms in Copenhagen, Hamburg and Amsterdam. The alarms in Copenhagen should not be visible as in-band management has gone off-line. Hamburg was expected to trigger a LoS on the VOA of the MUX where the signal from the 6500 in Copenhagen is picked-up.

### Test Results

Figure 4.17 shows a screenshot of the alarms observed during this test. As expected, critical alarms were raised in Amsterdam. Hamburg, however, did not generate a LoS alarm, but the CPL equipment did encounter a Domain Optical Controller Action Fault and a Gauge Threshold Crossing alarm. A possible explanation is the Amplified Spontaneous Emission (ASE) noise from the EDFAs between Hamburg and Copenhagen that confuse the CPL equipment in Hamburg. In Copenhagen there is no CPL equipment, hence, no such behaviour was observed in Test 1.

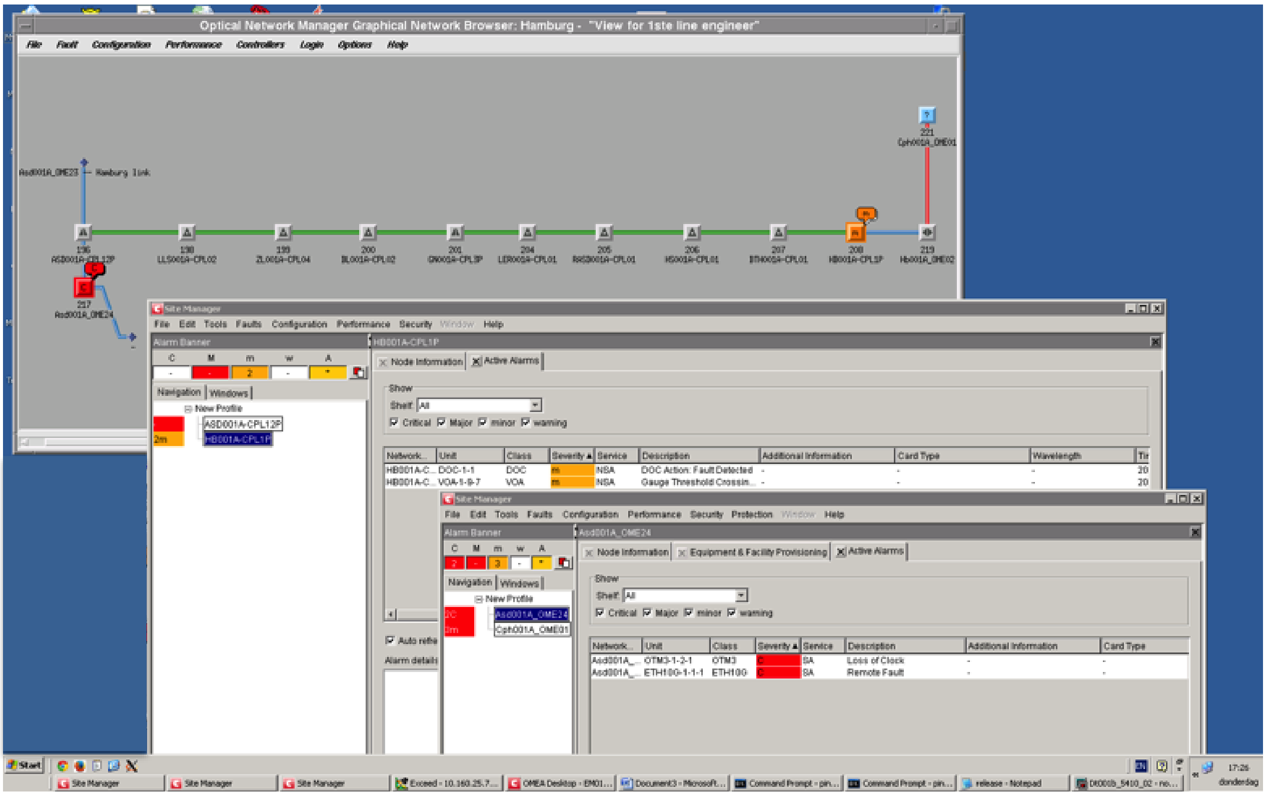



Figure 4.17: Critical alarms appear in Amsterdam; in Hamburg, the VOA where the signal from the 6500 Copenhagen is expected triggers a minor alarm

As in the case of Test 1 (Figure 4.12), in-band management to Copenhagen was lost. Out-of-band management remained (no screenshot is provided).

### Conclusions

From this test it can be concluded that for alien wavelength the alarms may appear different as ASE and optical signal may be interpreted incorrectly. In such cases, a change in received optical power should be considered as a LoS alarm. Correlation with a LoS alarm at the corresponding receiving Optical Line Termination (OLT) is required.

## 4.3.3.3 *Test 3: Signal Failures in the NORDUnet Domain*

### Objective

The third test was to perform the signal failure in the NORDUnet domain.

### Setup

NORDUnet shut down relevant ports on the WSS components in the Alcatel system.

Again referring back to Section 4.3.1, the shutdowns were performed in WSS point B ("add" side), and WSS point D ("drop" side), both in Hamburg. (In the test setup figure, Figure 4.18 below, these points are "2" and "8".)

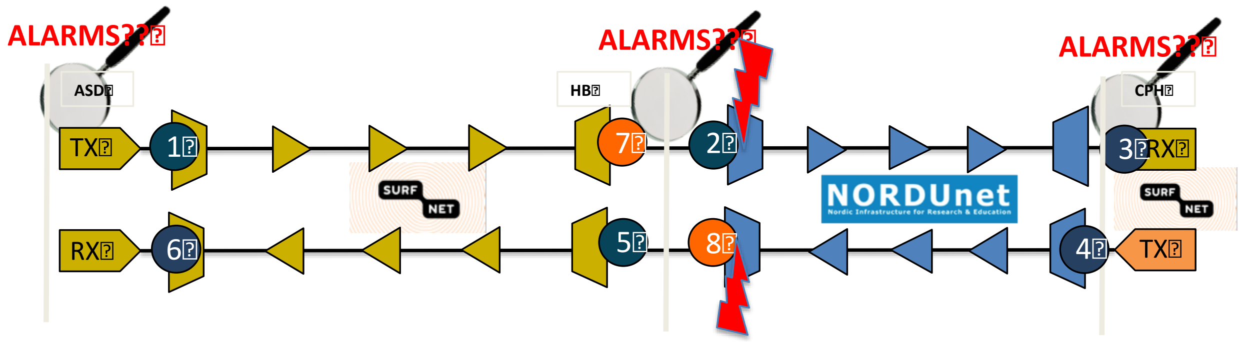



Figure 4.18: Test 3: Signal failures in the NORDUnet domain

The first shutdown was performed at the Hamburg add side (Amsterdam to Copenhagen); the second test was to shut down the drop side (Copenhagen to Amsterdam).

## NORDUnet Domain

### Expected Behaviour (Physical Layer Only)

The test basically simulates hardware failure in the NORDUnet domain at Hamburg, specifically the situation that would happen if the WSS component breaks down or an internal cabling fault occurs.

### Test Results: Shutdown on Add Side (from Amsterdam to Copenhagen)

| | Perceived Severity | Event Date and Time | Friendly Name | Alarm Type | Probable Cause (name) | Reservation Status | Clearing Status | Acknowled |
|---|---|---|---|---|---|---|---|---|
| 1 | MAJOR | 2013/10/24 15:41:36 | R5NU-HMB2-LM-02/r02sr1/board#14 | EQUIPMENT | Input Power Loss | NRSV | NCLR | NACK |
| 2 | MAJOR | 2013/10/24 15:41:14 | R5NU-ORE-LM-01/r1sr2sl14/port#1-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | NCLR | NACK |
| 3 | MAJOR | 2013/10/24 15:41:14 | R5NU-ORE-LM-01/r01sr2/board#14 | EQUIPMENT | Output Power Loss | NRSV | NCLR | NACK |
| 4 | MAJOR | 2013/10/24 15:20:52 | R5NU-HMB2-LM-01/r2sr2sl14/port#1-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | CLR | NACK |
| 5 | MAJOR | 2013/10/24 15:20:52 | R5NU-HMB2-LM-01/r02sr2/board#14 | EQUIPMENT | Output Power Loss | NRSV | CLR | NACK |
| 6 | MAJOR | 2013/10/24 15:20:51 | R5NU-HMB2-LM-02/r01sr1/board#14 | EQUIPMENT | Input Power Loss | NRSV | CLR | NACK |
| 7 | MAJOR | 2013/10/24 15:20:41 | R5NU-ORE-LM-01/r1sr2sl2/port#108-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | CLR | NACK |
| 8 | MAJOR | 2013/10/24 15:20:41 | R5NU-ORE-LM-01/r01sr2/board#02 | EQUIPMENT | Input Power Loss | NRSV | CLR | NACK |
| 9 | WARNING | 2013/10/24 15:13:23 | R5NU-HMB2-LM-02/r02sr1/board#14 | EQUIPMENT | Performance Degraded | NRSV | CLR | NACK |
| 10 | MAJOR | 2013/10/24 15:13:16 | R5NU-HMB2-LM-01/r02sr1/board#14 | EQUIPMENT | Input Power Loss | NRSV | NCLR | ACK |
| 11 | MAJOR | 2013/10/24 15:07:48 | R5NU-ORE-LM-01/r1sr2sl14/port#1-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | CLR | NACK |
| 12 | MAJOR | 2013/10/24 15:07:48 | R5NU-ORE-LM-01/r01sr2/board#14 | EQUIPMENT | Output Power Loss | NRSV | CLR | NACK |
| 13 | MAJOR | 2013/10/24 15:01:41 | R5NU-HMB2-LM-01/r02sr1/board#14 | EQUIPMENT | Input Power Loss | NRSV | CLR | NACK |
| 14 | MAJOR | 2013/10/24 15:01:40 | R5NU-HMB2-LM-02/r02sr1/board#14 | EQUIPMENT | Input Power Loss | NRSV | CLR | NACK |
| 15 | MAJOR | 2013/10/24 15:01:40 | R5NU-HMB2-LM-01/r2sr2sl2/port#108-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | CLR | NACK |
| 16 | MAJOR | 2013/10/24 15:01:40 | R5NU-HMB2-LM-01/r02sr2/board#02 | EQUIPMENT | Input Power Loss | NRSV | CLR | NACK |
| 17 | MAJOR | 2013/10/24 11:41:48 | Heuer/r1sr2sl18/port#8-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | NCLR | ACK |
| 18 | MAJOR | 2013/10/24 11:41:48 | Heuer/r1sr2sl18/port#6-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | NCLR | ACK |
| 19 | MAJOR | 2013/10/24 11:41:48 | Heuer/r1sr2sl18/port#5-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | NCLR | ACK |
| 20 | MAJOR | 2013/10/24 11:41:48 | Heuer/r1sr2sl18/port#4-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | NCLR | ACK |
| 21 | MAJOR | 2013/10/24 11:41:48 | Heuer/r1sr2sl18/port#3-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | NCLR | ACK |
| 22 | MAJOR | 2013/10/24 11:41:48 | Heuer/r1sr2sl18/port#2-OGPI | COMMUNICATIONS | Loss Of Signal | NRSV | NCLR | ACK |

Figure 4.19: Alarms on the Alcatel system caused by a shutdown on the add-side in Hamburg

The alarms in Figure 4.19 (orange rows 1–3) show that the signal fails at the drop side in Copenhagen. As there are no other alarms in Hamburg (the HMB2-LM-02/r02sr1/board14 is the alarm that appears when NORDUnet shuts down the WSS port in Hamburg), it indicates that the failure happened internally to NORDUnet.

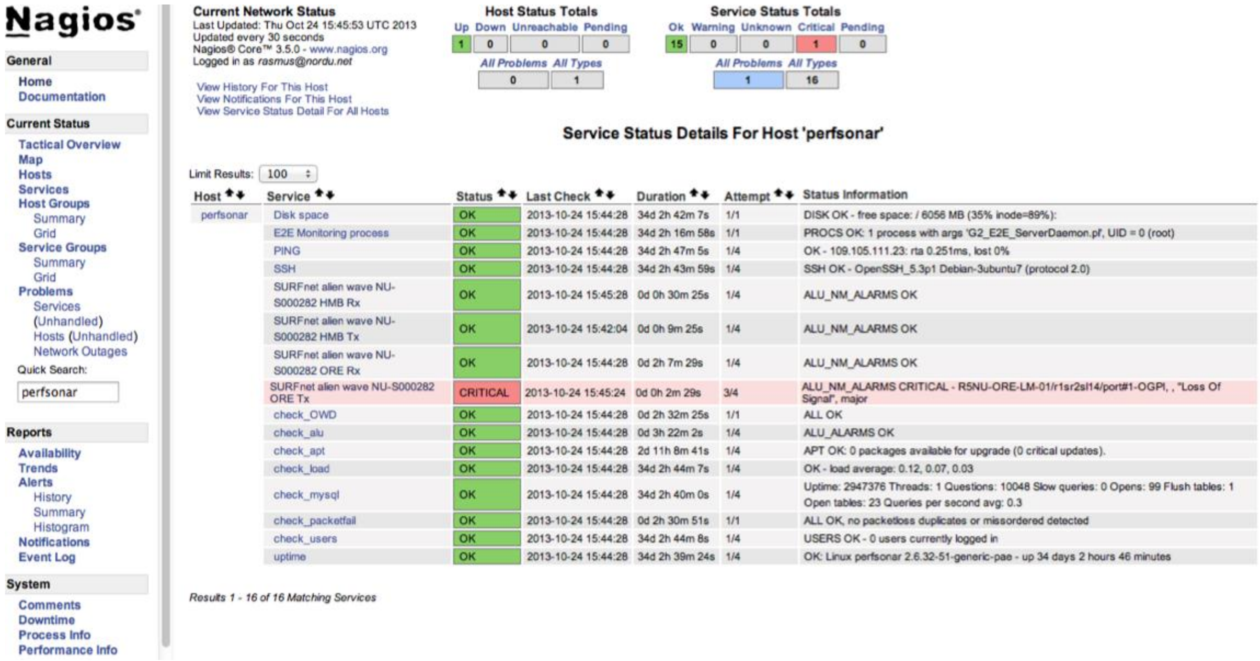



Figure 4.20: Alarms as reported by Nagios for the shutdown on the add side in Hamburg

Further, the alarm that was reported in the Nagios system (Figure 4.20) is also the alarm observed in the Alcatel network management system, specifically the problem at the WSS drop side in Copenhagen.

### Test Results: Shutdown on Drop Side (from Copenhagen to Amsterdam)

Similarly it was observed that, when shutting down the WSS component at the drop side in Hamburg, the alarm was only seen in Hamburg (Figure 4.21).

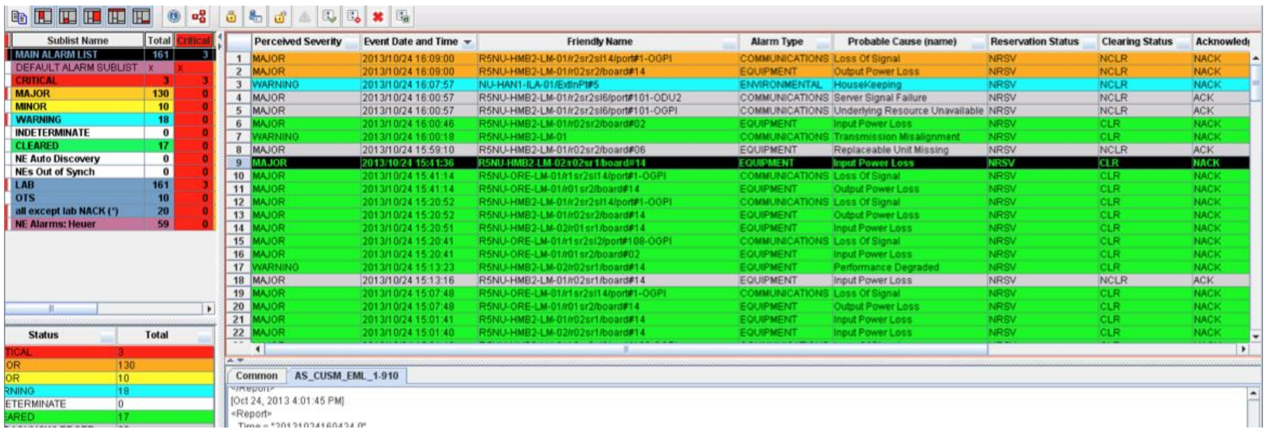


Figure 4.21: Alarms on the Alcatel system caused by a shutdown on the drop side in Hamburg

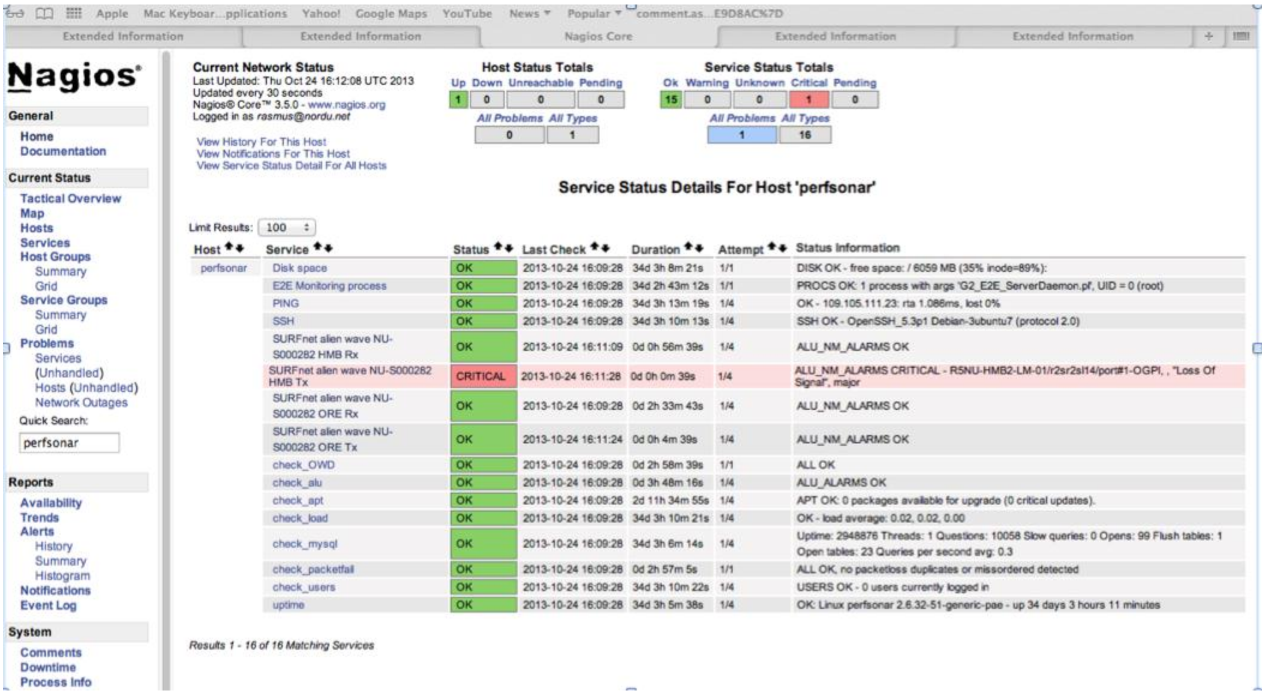



Figure 4.22: Alarms as reported by Nagios for the shutdown of the drop side in Hamburg

As expected, the alarm received in Nagios was the signal "drop" failure (HMB Tx) (see Figure 4.22).

## SURFnet Domain

### Expected Behaviour (Physical Layer Only)

In the case of an add-side failure in NORDUnet's domain in Hamburg, the CPL equipment was not expected to raise an alarm as there is no change in power levels anywhere on a CPL monitoring point. The 6500 in Amsterdam should not be aware of this failure except for the fact the system receives information from the Copenhagen system that will be affected because in Copenhagen the received signals will be lost on the 6500.

### Test Results: Shutdown on Add Side (from Amsterdam to Copenhagen)

When the add side was shut down in Hamburg, the 6500 in Copenhagen triggered a LoS (Figure 4.23). However, in Amsterdam (Figure 4.24), the 6500 still received a signal from Copenhagen and continued transmitting towards Copenhagen. The CPL equipment between Amsterdam and Hamburg therefore did not trigger an alarm. However, the systems could not communicate with one another. The observed representation of the alarms was according to the expectations.

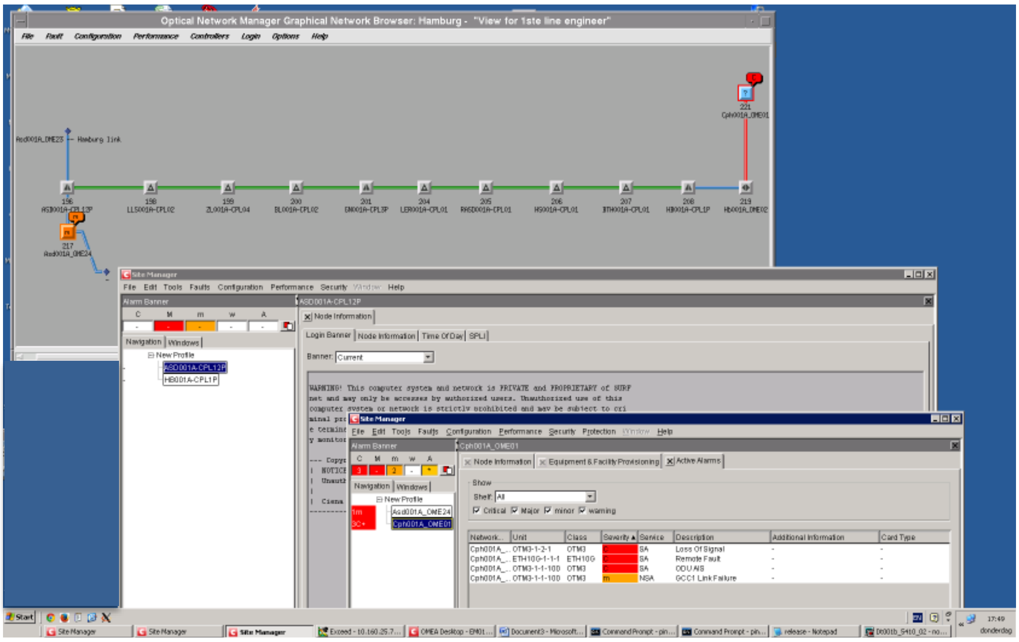



Figure 4.23: Shutdown of add side in Hamburg caused critical alarms in Copenhagen

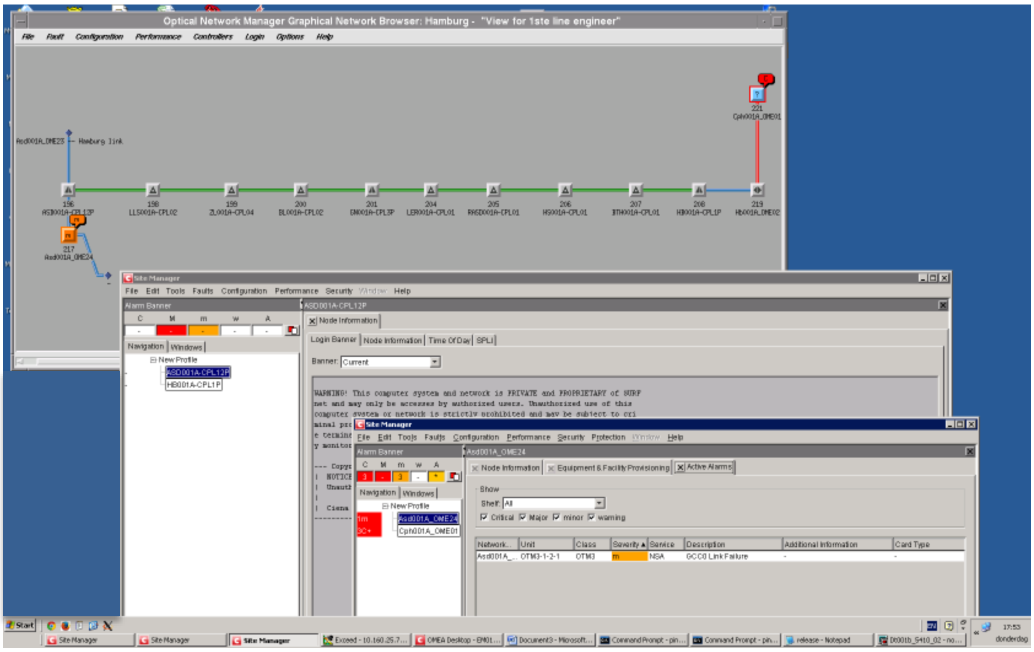



Figure 4.24: Shutdown of add side in Hamburg caused a minor alarm in Amsterdam

**Test results shutdown drop side (from Copenhagen to Amsterdam):**

When the drop side was shut down in Hamburg, no light was injected in the CPL link towards Amsterdam (Figure 4.27). As a result, the 6500 in Amsterdam triggered several critical alarms (Figure 4.26). Residuals of ASE build-up in the link caused an “RX Power Out Of Range” error and the lack of an optical signal caused a loss of clock failure. In Copenhagen, the 6500 received an optical signal and transmitted a signal. As in the case of the add-side shutdown, only minor errors occurred (Figure 4.25) as the information that was transmitted was not received in Amsterdam and the 6500 in Copenhagen never received the results.

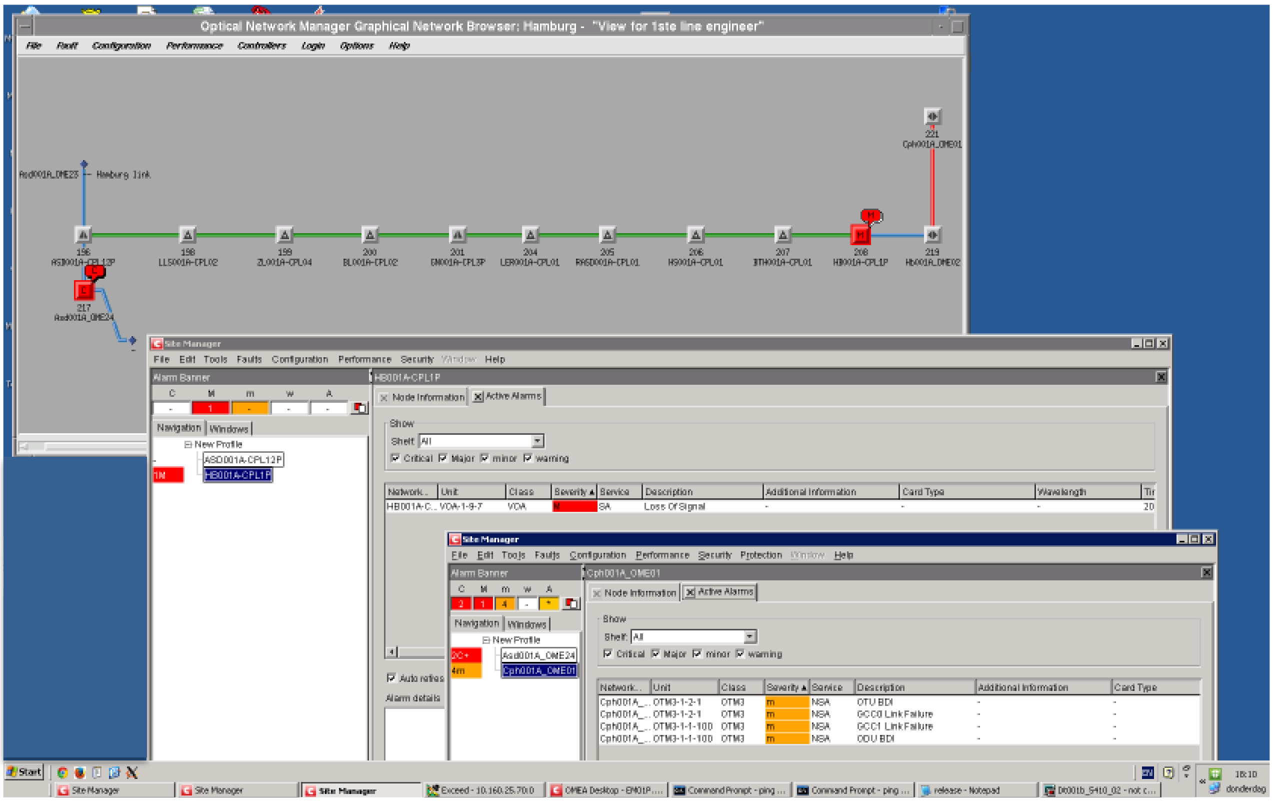


Figure 4.25: Shutdown of drop side in Hamburg caused minor alarms in Copenhagen

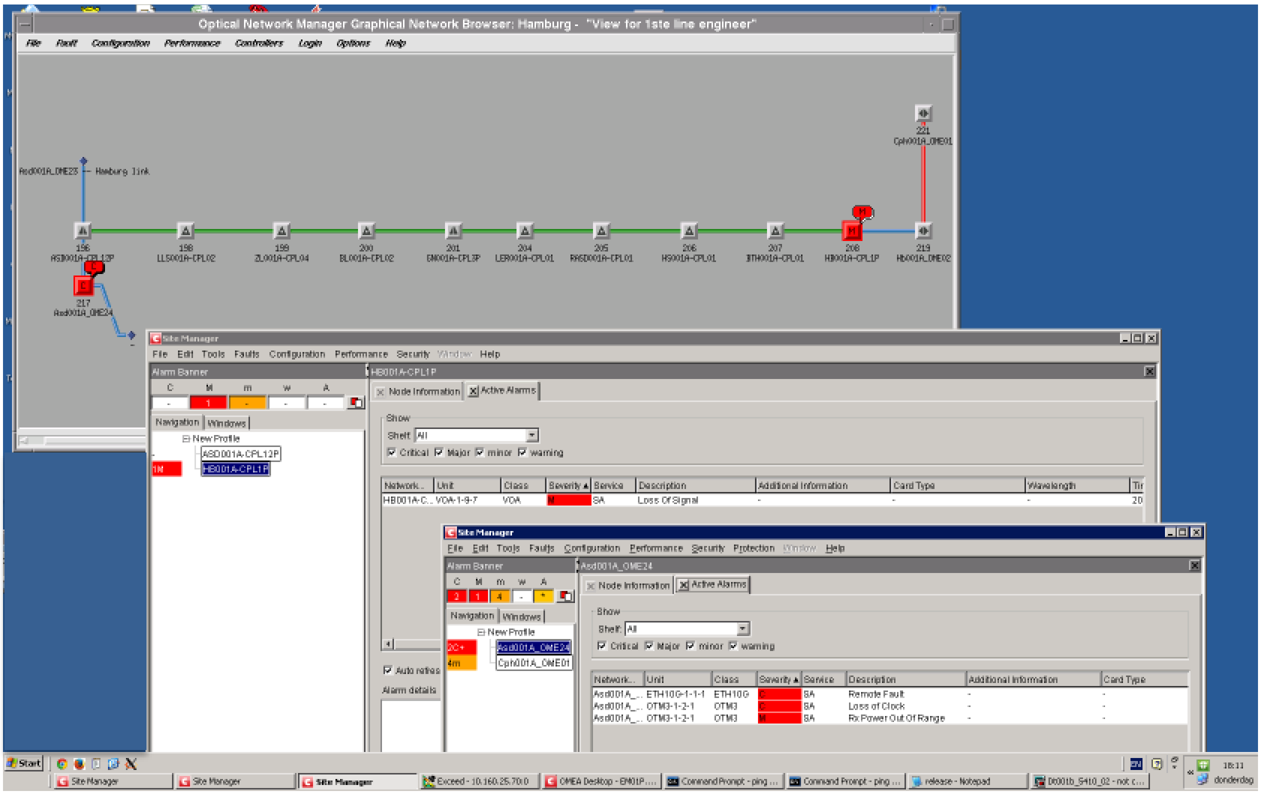



Figure 4.26: Shutdown of drop side in Hamburg caused major alarms in Amsterdam

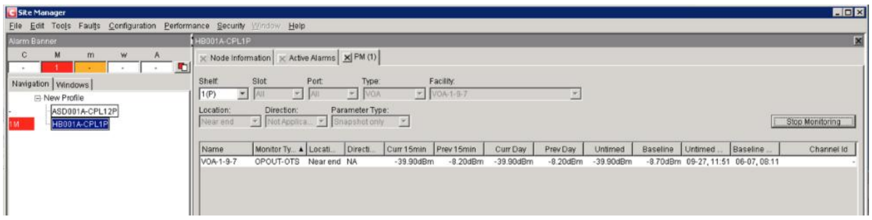



Figure 4.27: Absence of a line signal on the VOA in Hamburg from the drop side of NORDUnet

After the testing was concluded, all failure simulations were restored and both parties waited until all alarms cleared (Figure 4.28 and Figure 4.29).

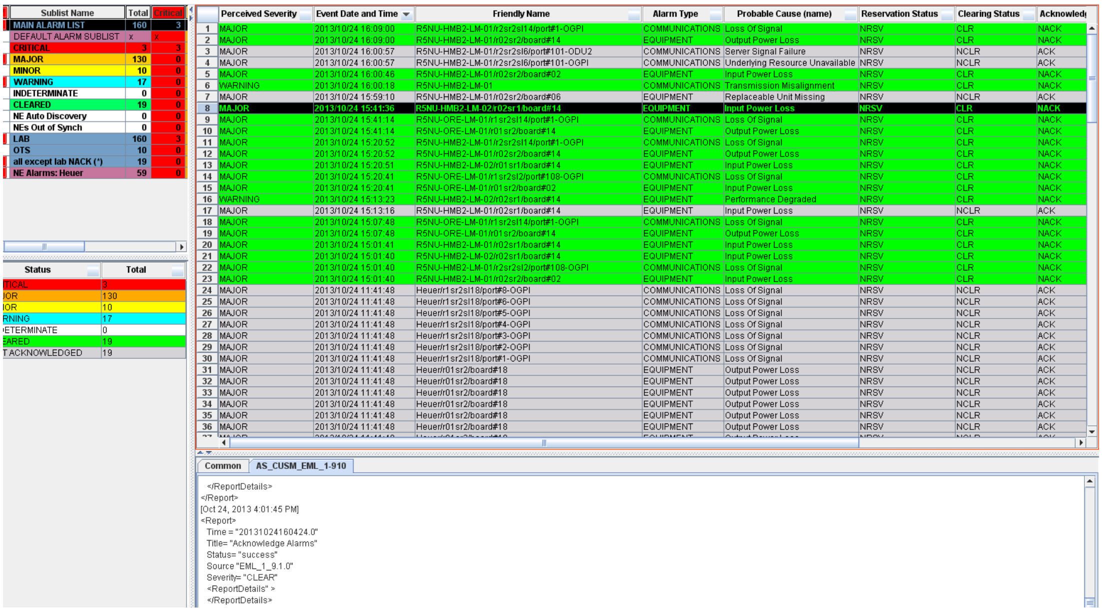


Figure 4.28: Cleared alarms: Alcatel system

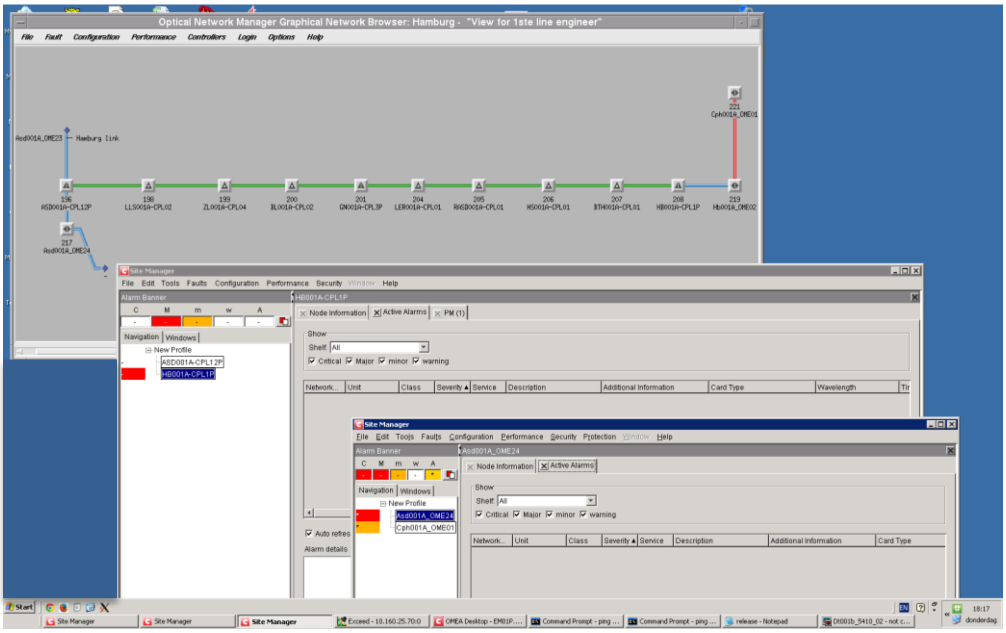



Figure 4.29: Cleared alarms: CPL and 6500 Ciena systems

## 4.3.4 Conclusions

From the tests it can be concluded that, in general, the behaviour of the control and management systems was in line with expectations.

Unexpected behaviour can be contributed by the optical systems that misinterpret ASE from a different domain as if it were an optical signal.

The NOC engineers at SURFnet interpreted the alarms correctly, including the alarms that deviated from what was expected.

## 4.4 Integration of Nagios with Zenos / OneControl

As mentioned in Section 4.3.2, NORDUnet has implemented the Nagios system for implementing OSS functionalities. SURFnet is currently migrating to OneControl, a Ciena proprietary solution. In the ideal situation, Nagios would provide information on input and output power levels of in-line amplifiers while OneControl would provide information on BER performance at both end points of the link, input and output powers of in-line amplifiers as well as the receiving and transmitting powers at the boundaries of the domains.

NORDUnet has completed the integration of OAM functionality into Nagios, while implementation of the above-mentioned functionality in the SURFnet domain has been postponed because of the transition to OneControl. As the original intention was to implement on Zenos, a first analysis revealed that the major challenge lies not in obtaining the data, but in representing topologies so that it is clear to both domains what the names of the locations, the equipment and the parameters are, and how to interpret the values. The lack of unified naming manifests itself in the same way as, for example, patching requests between domains is often difficult and labour intensive. For SURFnet, given its technical and organisational implementation of OSS functionality, it is important that an OAM configuration responds automatically to changes in topology and equipment configuration.

# 5 perfSONAR Solution

SURFnet initially started to implement the sharing of monitoring information on alien wavelengths using the E2EMon tool of the perfSONAR framework. However, during implementation, problems occurred that could not be resolved given limited resource availability and limited community support: support of E2EMon ceased in February 2013 [DS1.3.2,4]. Instead, a new monitoring solution is proposed, named CMon (Circuit Monitoring), to be developed during the GN3plus project (by SA4 Network Support Services). At the time of writing it is not clear to what extent this solution supports alien wavelengths.

# 6 Conclusion/Next Steps

Operation of a 40 Gbit/s alien wavelength service between Amsterdam and Copenhagen has been activated. The data plane operates in a stable manner and is free of transmission errors. It has been found that reduction of the optical powers injected into the Alcatel-Lucent system greatly improves performance.

In the context of monitoring alien wavelengths, a monitoring framework is essential. When more domains and systems are involved, manual or procedural fault detection and isolation becomes complicated and time consuming. Implementation efforts have also indicated that existing frameworks that do not specifically target alien wavelength may not always align with the practices and procedures implemented by NOCs.

Processes and procedures are in place, with NORDUnet implementing monitoring as part of its Nagios OSS. SURFnet has chosen to implement OAM functions manually until migration to a new OSS has been completed. SURFnet proposes a review of high-level requirements.

Testing essentially confirmed the expectations and generated new ideas to improve the operational tools. As the monitoring can only be done at L0, some maintenance tools are difficult to implement (e.g. maintenance signal interaction such as Alarm Indication Signal (AIS), Backward Defect Indication (BDI), etc.), while improvements to pure optical monitoring are definitely possible. For example, signal degradation thresholds can be configured to fit the exact path of the alien wave, thus enabling monitoring of performance parameters. Furthermore, functions like spectrum analysis and channel margins read-outs are available in the systems and hence are also likely to be adopted in the monitoring.

In addition to simply providing parameters and values, the ideal monitoring framework should understand what alarms in neighbouring domains mean and how alarms in different domains should be interpreted and linked to alarms observed in one's own domain. This could increase the value of a monitoring system and speed up fault isolation and disaster recovery as information is interpreted in a more sophisticated way.

# References


| | |
|---|---|
| **[DS1.3.2,4]** | GN3-13-060 “Deliverable DS1.3.2,4: Annual Advanced Services Usage Report” http://geant3.archive.geant.net/Media_Centre/Media_Library/Media%20Library/GN3-13-060_DS1-3-2-4_Annual_Advanced_Services_Usage_Report.pdf |
| **[G.698.1]** | ITU-T Draft Recommendation G.698.1 “Multichannel DWDM applications with single-channel optical interfaces” http://www.itu.int/rec/T-REC-G.698.1-200911-I/en |
| **[G.698.2]** | ITU-T Recommendation G.698.2 “Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces” http://www.itu.int/rec/T-REC-G.698.2-200911-I |
| **[Zenoss]** | http://community.zenoss.org/index.jspa |


# Glossary

| | |
|---|---|
| **AIS** | Alarm Indication Signal |
| **ASE** | Amplified Spontaneous Emission |
| **AW** | Alien Wave |
| **BDI** | Backward Defect Indication |
| **BER** | Bit Error Ratio |
| **CAPEX** | Capital Expenditure |
| **CBF** | Cross-Border Fibre |
| **CMon** | Circuit Monitoring System |
| **CPL** | Common Photonic Layer |
| **DGD** | Differential Group Delay |
| **DWDM** | Dense Wavelength-Division Multiplexed |
| **E2EMon** | End-to-End Monitoring System |
| **EDFA** | Erbium Doped Fibre Amplifier |
| **FEC** | Forward Error Correction |
| **IMS** | Inventory Management System |
| **IP** | Internet Protocol |
| **ITU-T** | International Telecommunication Union – Telecommunication Standardisation Sector |
| **L*n*** | Layer *n* |
| **LM** | Light Manager |
| **LOS** | Loss of Signal |
| **MUX** | Multiplexer |
| **NMS** | Network Management System |
| **NOC** | Network Operations Centre |
| **NREN** | National Research and Education Network |

| | |
|---|---|
| **NRZ** | Non-Return to Zero |
| **OADC** | Optical Add/Drop Coupler |
| **OAM** | Operation, Administration and Maintenance |
| **OAM&P** | Operation, Administration, Maintenance and Provisioning |
| **OEO** | Optical-to-Electrical-to-Optical |
| **OLT** | Optical Line Termination |
| **OOK** | On/Off Keying |
| **OPEX** | Operating Expenditure |
| **OSNR** | Optical Signal to Noise Ratio |
| **OSS** | Operations Support System |
| **PMD** | Polarisation Mode Dispersion |
| **PM-QPSK** | Polarisation Multiplexed-Quadrature Phase Shift Keying |
| **PoP** | Point of Presence |
| **ROADM** | Reconfigurable Optical Add/Drop Multiplexer |
| **RX** | Receiver |
| **SNMP** | Simple Network Management Protocol |
| **SPM** | Self-Phase Modulation |
| **TX** | Transceiver |
| **VOA** | Variable Optical Amplifier |
| **WSS** | Wavelength Selective Switch |
| **XPM** | Cross-Phase Modulation |