Routing in Translucent Networks -
Motivations and Objectives of
EURESCOM P1202 Project

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Abstract
The recent availability of new optical network elements makes possible to introduce new architectures and new functionality into the optical transport networks. Optical cross-connects and ultra long haul transmission equipment have emerged and opened a new opportunity to handle fully transparent connections and extend optically transparent domains.

A translucent network is basically a network in which the network functions (transmission, routing, supervision, performance assessment, and survivability) are mainly performed in the optical domain. However, the use of opto-electronic components (e.g. components providing functions like wavelength conversion and 3R regeneration) to improve the performance of the translucent networks is not precluded.

The current paper briefly introduces EURESCOM P1202 Project “Routing in Translucent Networks”, and presents some illustrative results on the resource utilization aspects of transparency in optical networks.

Introduction
On networks around the globe, traffic volumes are swelling and capacity demand is growing. To meet large capacity needs the WDM optical networks are being introduced by numerous network operators. The growth in demand for bandwidth in the transport network has been driven largely by the growth of new IP based traffic.

Network growth patterns in many cases are not predicted by the traditional traffic models that have been used to plan and provision network capacity. As a result, network resource allocation often falls short of meeting the demands for bandwidth placed on the transport network by new services. The short fall in meeting the demands for new services is based largely on time consuming manual setup of network connections.

As soon as new services, requiring very high bandwidth, becomes available, networks’ customers are likely to ask a direct optical connectivity at a low price. As a consequence, the number of optical point-of-presence in the network increases, while the traffic generated from a single network node requires high bandwidth only for a limited time.

It is becoming increasingly recognised that automation of the OCh layer network is both practical and useful. There is clearly a benefit from automatic switching of optical channels; in particular, there is a clear opportunity to create a global switched optical network. There are a number of value added capabilities proposed for such a solution:
Reactive traffic engineering: This is a prime attribute and allows the network resources to be dynamically allocated to routes.

Restoration and recovery: These attributes can maintain graduated preservation of service in the presence of network degradation.

Linking optical network resources to data traffic patterns automatically will result in a highly responsive and cost effective transport network.

Under these perspectives Automatic Switched Optical Networks (ASONs) offer to the operator additional means for the efficient use of the networks resources and, hopefully, for reduction of network costs.

ASON improves the OTN’s features, providing OChs with the switching functionality, which means that an OCh connection can be established, maintained and released on signalling basis. As a result, ASON allows dynamic and fast provisioning of connection through an optical transport network and automate the rules for enforcing SLA (Service Level Agreement).

Automatic Switched Optical Networks

The ASON has to be seen as a successor of the OTN with extended functionality. As a result of the separate control plane, the ASON can perform a set of automatic functions that enhance significantly the network reconfiguration flexibility; save network operation costs and support new OCh services.

ASON, in providing multi-client services, is characterised by a control plane that manages network elements in the optical transport network plane (Figure 1).

![Figure 1 Logical view of ASON architecture](image)

The ASON is intended to allow switching of (optical) network connections within the Optical Transport Network (OTN) under control of its own signaling network (Figure 1). ASON definition implies the existence of three separate planes in the network:
the optical transport plane which provides the functionality required for the transport of the client signals of the ASON; in particular, it provides the capability to cross-connect the characteristic information of the optical channels;

• the ASON control plane which provides the functionality required for establishing end-to-end connections of client signals with the properties (in terms of protections applied, duration and time scheduling of the connection, etc.) that are specified by the customer himself during connection set-up phase;

• the management plane, which performs management functionality, related both to the transport plane and to the control plane.

Translucent Networks

Translucent transport network concept is a step ahead towards an intelligent automatic optical transport network. Translucent Networks represent an evolutionary step that offers further improvement in cost-efficiency, because of their protocol and data format independent transmission. In the translucent transport network concept physical limitations are included in the routing protocol with optional o-e-o conversion and 3R-regeneration, when a performance increase or wavelength conversion is needed.

With the advance of all-optical network nodes and increasing transmission lengths a concept for handling transparent connections including the physical limitations is needed on the protocol level. This will simplify the functional network concept and will allow significant cost reduction due to reduced number of transponders and will lead to maintenance cost benefits for carriers.

In the concept of the translucent transport networks point-to-point optical links are interconnected by optical cross-connects and form a transparent optical domain that allows cost effective protocol and data format independent transmission. This transparent domain could be nation wide or pan-European domain for international carriers. However, in such a transparent optical domain physical effects like amplifier noise, fibre dispersion, nonlinearity and cross-talk accumulate and degrade the signal quality. In order to prevent an unacceptable level of signal degradation these factors have to be taken into account in the routing protocols.

EURESCOM P1202 Project – Routing in Translucent Networks

In EURESCOM P1202 project titled "Routing in Translucent Transport Networks" a concept for including physical limitations in the routing protocols in translucent transport networks will be developed [1]. The new concept is investigated theoretically and as far as possible experimentally in co-operation with vendors in a reference network.

Addressed issues are as follows:

• Identify all those optical transmission impairments that can affect a nation or Europe wide optical transport network;

• Provide a catalogue of reference network scenarios of translucent TNs in which the simplified optical transmission impairments are considered;

• Provide requirements for a routing protocol that takes into account the simplified optical transmission impairments;

• Evaluate existing translucent routing protocols;
Aims at implementing a routing protocol meeting the operator requirements and evaluate it experimentally in a reference translucent TN in cooperation with vendors. The concept of the translucent transport network is a new approach and the project offers a good opportunity to evaluate this concept. The following results are expected:

- A catalogue of reference network scenarios of translucent TNs, in which main optical transmission impairments are considered;
- A set of requirements for a routing protocol that takes into account the main optical transmission impairments;
- Theoretical and experimental evaluation of the reference translucent TN and its routing protocol.

Illustrations for the motivations

Due to the limited size of transparent optical islands o-e-o conversion based 3R functions are needed in selected nodes to cover large size networks. Besides to improve signal quality, o-e-o conversion based 3R function enables wavelength conversion, as well. Wavelength conversion may be needed to interconnect different administrative domains in a multi-operator environment, or just to improve the efficiency of resource utilization.

It is well known from the theory that in an optical network not equipped with wavelength conversion functionality, the utilization of link capacities may be poor, since the overlapping of different lightpaths may block some optical channels. To illustrate this feature in static (OTN) and dynamic (ASON) case a small network example is elaborated.

A simple service model is assumed: There are communication needs varying in time between a set of source-destination pairs. The variation is simple, in a certain period of time there is a need for an optical channel, in the rest of time there is not, in other words the sources are on-off like ones. In case of OTN a dedicated optical channel should be provided for each source-destination pair, regardless the time varying needs, since OTN is not capable of fast reaction in case of demand changes. However, in case of ASON dedicated channels are needed only from source/destination point to the nearest ASON switch, and switched connections can be applied among ASON switches according to the time varying requests. Due to the time varying requests, the automatic switching capabilities of ASON can achieve statistical gains in terms of the number of required channels.

A simple uniform traffic pattern specifies the number of structure of on-off source-destination pairs requiring dedicated optical channels in OTN case (Figure 2a), and representing dynamic channel requests in ASON case (Figure 2b). The dynamic requests are characterized by a fixed mean holding time for an on-period. Specifying a given amount of offered traffic, the mean duration of an off-period can be calculated. Thus, the impact of dynamic traffic from on-off sources with different activity (or filling) rates (filling_rate=E(on_time)/E(on_time+off_time)) on wavelength assignment and link utilization can be studied.

For OTN dimensioning shortest path routing and optimal wavelength allocations under fixed routes are applied, for dynamic ASON traffic shortest path routing and first fit wavelength assignment are assumed.
Link capacity utilization is expressed with help of two values:

- the number of channels in use on the given link,
- the number of wavelengths required (or to be provided) on the given link (which determines the capacity).

The rate of these two values provides a good indication of the efficiency of link utilization. If the wavelength conversion functionality is present in each node there is no restriction on wavelength assignment, it can be performed link by link independently, and the above specified efficiency rate is one. If there is no wavelength conversion functionality present in nodes, the same wavelength should be assigned end-to-end to a connection and then the efficiency can be smaller than one.

Chart 1 compares resource needs, expressed by the product of the number and length of optical channels, between OTN and ASON with transparent nodes and without protection.

![Figure 2](attachment:figure2.png)  
**Figure 2** Corresponding OTN and ASON models for comparisons in case of on-off traffic sources

The resource needs are calculated with the number of channels in use (used channels in Chart 1) and with the number of wavelengths required (peak wavelengths in Chart 1). The latter corresponds to the resources (or capacity) to be installed in the network. In case of OTN, the difference is the penalty due to the absence of wavelength conversion. Due to the transparent wavelength assignment and the no wavelength conversion, there are optical channels not in use on OTN links. In case of ASON, the resource needs for used channels converge to the OTN's counterpart at high filling rate, as expected. Since the number of source-destination pairs is the same in both cases and at high filling rates there are no statistical gain from switching.

For ASON, the resources to be installed are significantly higher than those for the OTN are. The difference stems from the penalty due to the dynamic wavelength allocation (and tear-down). The applied ASON routing algorithm performs a “first fit” strategy based wavelength allocation along the fixed primary path. Due to the dynamic behavior of traffic in ASON, the
pattern of used channels is continuously changing; thus, it is impossible to have an optimal wavelength allocation in any current traffic configuration. However, in OTN the wavelength allocation is optimal (sub-optimal due to the applied heuristics) for the specified transport capacity demands.

**Chart 1**  Comparison of OTN and ASON resource needs (in terms of OCh*km), not protected transparent case

Since the curve representing ASON resource needs crosses the OTN one at about 50% source activity rate, no statistical gain is expected above this filling rate.

It is known, as well, that the number of hops (i.e. transparent nodes traversed) on the connection has a significant impact on the efficiency of wavelength allocation in networks without wavelength conversion. To illustrate qualitatively, specific network examples are constructed with two, three, four, five and six-hop paths. Specific dynamic traffic patterns are considered to provide the same load on each link. First, each case is dimensioned for the specified traffic, and then link utilization is studied. Chart 2 illustrates the impact of the number of hops on the wavelength allocation obtained from this study. The link utilization is depicted as a function of the total network load for different numbers of hops in path. From Chart 2, two-hop paths result in 70-80% link utilization, with three-hop paths the utilization decrease to 60%, with four, five, or six-hop paths to 50%. The higher dynamicity - the one order change of the traffic load - has significant impact on the link utilization in case of two-hop paths. (The networks are dimensioned to carry the increased traffic in each case). This study shows that the link utilization can be increased by decreasing the
number of hops through an appropriate introduction of OEO elements on a transparent path. This makes up one motivation for translucent networks.

**Chart 2**  
*Impact the number of hops in paths on link utilization in a full transparent ASON (without wavelength conversion) under dynamic traffic (no blocking) and shortest path routing*

**Summary**

Translucent network concept and the routing in translucent networks are important issues in the progress of optical network technology and applications. The intelligent application of optional o-e-o conversion and 3R-regeneration in the routing protocol, when a performance increase or wavelength conversion is needed will simplify the functional network concept and will allow significant cost reduction due to reduced number of transponders and will lead to maintenance cost benefits for carriers.

EURESCOM P1202 “Routing in translucent networks” Project launched early 2002 will study the theoretical and practical aspects of this new network concept. The current paper summarized the starting points, the addressed issues and the expected main achievements of the ongoing project.

**Note**

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