Transient control in ASONS

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***Abstract*— This paper discusses tradeoffs between local and supervisory control of transients in ASONs. A motivating example of control of a backward pumped Raman amplifier illustrates these tradeoffs.**

Optical communications, Control, Raman Amplification, ASON

I. INTRODUCTION

The Control Plane for an ASON, shown in Figure 1, can set up an optical path in response to a request from a customer or the Network Management Centre (NMC). The current protocols [1], such as GMPLS, ASON/ASTN and OIF-NNIs, focus on path management only in so far as the following:

- Determining path availability for the requested service,
- Reserving resources for the path and releasing them after path has been removed,
- Configuring the Network Elements (NEs) for path set-up, maintenance, modification and tear-down.

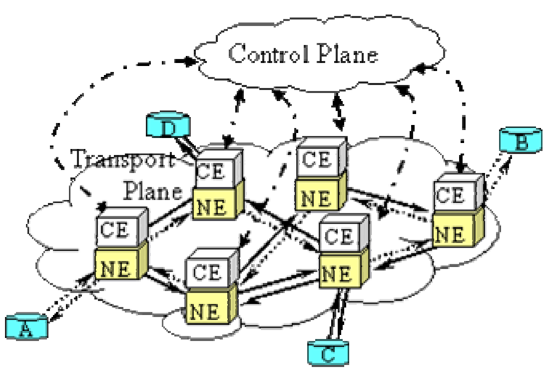

Figure 1 The Control Plane provides path set-up, modification, maintenance and tear-down by sending standardised messages to the Networks Elements (NE) via the Control Elements (CE). The standardised messages do not address issues such as changes in the operation point of optical amplifiers in the links between the NEs.

Control Plane communications are achieved using an IP protocol limiting the reliability of timing in control messages around the network. Beyond the functions listed in the dot-points above, the current standards do not include control of optical elements such as amplifiers or dispersion compensators.

Despite this, transients will occur in ASONs either through faults or as a result of path selection and other mechanisms. Further, any optical amplifiers in the network will exacerbate such transients [2]. Transient suppression thus requires (a) localised (feedback) control of the optical elements, and (b) communication between the NMC and the local control loops. This paper discusses the implications of the omission of these control issues from the current standards. This discussion is illustrated via a simulation of a controlled backward pumped Raman amplifier, subjected to transients as will arise from operation within an ASON.

II. SOURCES OF TRANSIENTS IN ASONS

The NEs in a network path can be devices such as Reconfigurable Optical Add/Drop Multiplexers or Optical Cross Connects. Between these NEs there will be an optical link which will most likely include optical amplifiers such as Erbium Doped Fibre Amplifiers or Raman Fibre Amplifiers.

When a path is set-up, modified or torn down, there will be transients in the optical power levels in the fibres of that path. These transients occur as optical channels are added or removed from the fibre in the path. In some cases, although the channel count may remain the same, the source of data on one or more wavelengths will change. These changes will impact the optical amplifiers in two ways. Dynamically, they will cause transients in the optical amplifiers output power levels. Statically, they will change the operating point of the amplifier. These transients and changes in operating point can have a significant impact on the Bit Error Ratio (BER) of the propagating signals.

The typical ASON protocols do not include methods to mitigate the impact of these changes. For example, a request for extra services on a link with 8 channels may result in the channel count in that link increasing, leading to a substantial increase in the optical power in that link, thereby changing the amplifiers' operating points. To ensure the same gain per channel before and after the extra channels are set-up, the optical amplifiers will require extra pump power .Without this change in operating point, the signal strength at the receive points may degrade to the extent of producing an unacceptable increase in the BER. When the extra channels are "energised", the optical amplifiers will experience a sudden increase in input power, resulting in a transient gain excursion in each amplifier in the link. Consequently, propagating transients would be commonplace in an ASON.

III. EXAMPLE OF AMPLIFIER TRANSIENTS AND CONTROL

Loopshaping is a relatively mature, linear, robust control design tool applicable to "open loop" systems modelled by finite dimensional linear equations (for example, systems of linear ODEs, but not PDEs) [3]. The resulting controller is robust (in a system theoretic sense) in that it can be designed to minimize the effect of noise (over pre-specified frequency bands) on the closed loop.

In order to apply loopshaping to backward pumped Raman amplifier control, the attendant PDE model for the amplifier must first be linearized about a steady state "operating point" (actually a function) that corresponds to the steady state spatial evolution of pump and signal powers propagating along the fibre. The resulting linear PDE model is spatially discretized along the fiber length, yielding a large system of linear ODEs. Model reduction (based on Hankel singular value truncation) is applied to reduce that model to a relatively small system of linear ODEs that dominate the open loop behaviour. The loopshaping design tool is then applied to this reduced order model, yielding a low order controller. Finally, signal power measurements were assumed to be generated by two band limited photo-diodes, one per half of the signal spectrum.

Figure 2 shows transients due to a change in the signal power reference provided by the control plane in response to a service request, and (a) due to channels dropped as a result of a system fault or a network reconfiguration and (b) due to a uniform input signal power decrease. The controller has been designed to implement signal power reference tracking, but not to compensate for signal power dropout or gain regulation. This is illustrated for the transient beyond 1500µs in (a) where the performance of the closed loop has significantly degraded.

IV. LOCAL AND SUPERVISORY CONTROL OF OPTICAL ELEMENTS

The example above shows that localised control requires a fast measurement of the energised channel powers and wavelengths in order to achieve transient control and spectral gain flatness. Such measurement capability for each amplifier is likely to add considerable expense. Similar issues are likely to arise for other optical elements in the network.

Supervisory control requires sufficient information to be transmitted in a timely fashion to the local control loops in order to implement the transient control on a global scale. This requires a substantial addition to the ASON standards. It is worth noting that implementation of pre-emphasis in an optical link is an example of supervisory control [4].

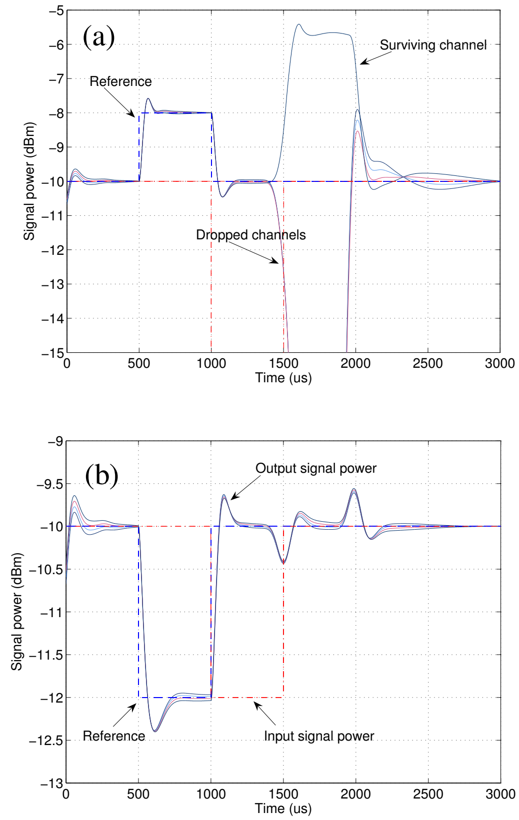

Figure 2. Transient response of a backward pumped Raman amplifier subject to set point change and (a) channel drop and (b) input channel power decrease.

V. CONCLUSION

The interplay of ASON dynamics with optical amplifiers produces transients which can only be suppressed with sufficient knowledge of the signal channels at the amplifier. This information can only be obtained via measurement at the amplifier in the case of local control, or using information transmitted via the Control Plane. This latter option requires extension of the current standards.

VI. ACKNOWLEDGEMENT

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