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Survey Paper

Challenges and requirements of a control plane for elastic optical networks

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ABSTRACT

Elastic optical networks have emerged as a promising technology for the efficient use of optical network resources. Its adaptable characteristics and adjustable data rate enable operators to meet the diverse granularity of their clients needs. In order to automate an elastic optical network operation, a control plane is required. Wavelength Switched Optical Networks (WSON) may already rely on a robust control plane which enables dynamic network management, provides prompt demand reply optimizing spectrum use, and implements important network features as survivability strategies, differentiated service, and grooming procedures. Due to its specific characteristics, elastic optical networks may not implement traditional WSON control plane solutions without further enhancement. Therefore, recent research efforts have been focusing on developing the control plane for this new technology, in most cases by proposing extensions to the currently available architectures. This paper describes a survey on the current ongoing research efforts to define elastic optical network control plane architecture. It identifies and classifies the most relevant proposals currently found in literature, and discusses how these propositions address the main requirements to design a control plane which enables automating the specific functions of an elastic optical network.

1. Introduction

Recent studies show a continuous growth of data traffic demand as a trend in the Internet evolution. Core network data traffic has been doubling in value almost every two years and is likely to continue growing exponentially [1,2]. Based on the current optical network development situation, it is hard to predict whether technology advances will be able to cope with the intense growth of resources requirements [3].

The fine granularity required by clients bandwidth is another demand upon the Internet, for it is not frequently met by the rigid Wavelength Switched Optical Networks (WSON) structure used by transport networks. In a WSON, a whole wavelength is usually assigned to a connection and the amount of resources it does not use is usually not shared between other connections [4]. Ad interim, network operators are now moving their long-haul connection services from 10 Gbps to 40/100 Gbps due to the proliferation of high bandwidth applications, while continuous traffic growth indicates 400 Gbps and 1 Tbps is expected to be a requirement in the long term.

Impelled by the foregoing facts, in the last half decade, research community and data transport providers have

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been demonstrating increasingly high interest in elastic optical networks (EON) – also known as Spectrum Switched Optical Networks (SSON). Its adaptability to the clients requirements and the promising ability to enhance optical network performance promotes EONs as a potential provider for future Internet needs. EONs are based on the flexible use of the optical spectrum as is described in [5] and known as flexi-grid. Instead of traditional spectrum bands, spaced usually by 50 or 100 GHz, each one able to accommodate an individual wavelength with a flexi-grid, optical spectrum can be partitioned in narrower bandwidth slots. The resulting spectrum slots can be adaptively allocated in order to meet diverse clients connection requirements. Alternatively, when a large amount of spectrum slots are jointly allocated, the resulting channel may reach bit rate as high as 400 Gbps, 1 Tbps [6,7]. The so-called super-channels are able to meet core networks intense bandwidth requirement growth. Therefore, the new concept of SSON is defined as an extension of WSON with flexible capabilities, i.e., a data plane connection is switched based on an optical spectrum frequency slot with variable width, rather than based on a single wavelength within fixed grid and with fixed channel spacing such as it is for WSON. Fig. 1 depicts a WSON network, where different data rates are accommodated in its rigid frequency grid independently of their actual spectrum occupancy and an SSON network where each data rate occupies a variable slot width.

Generalized Multiprotocol Label Switching (GMPLS) is the *de facto* control plane for WSON; it enables automated connection provisioning, bandwidth adjustment and recovery operations. The introduced flexible grid implies some changes on GMPLS controlled optical networks. Mechanisms supporting dynamic resource assignment, bandwidth variation, as well as protocols extensions are still unresolved issues and under current research and standardization by the International Engineering Tasking Force (IETF) [7]. At the same time, alternative control plane architecture has been recently proposed based on software defined networks (SDN), more specifically the OpenFlow protocol described in [9,10].

In this paper we present a survey on the current ongoing research efforts for defining an EON control plane architecture. We identify the most relevant proposals currently found in the literature, and classify the different control plane enhancement proposals into various categories according to the procedure they automate. In Section 2, we briefly introduce the EON environment. In Section 3 we explain the current developments and enhancements of path computation for EON and their impact on control plane requirements. Section 4 reports on the current extension standardization proposals for EONs control plane architecture. Finally, we present our concluding remarks in Section 5.

2. The SSON reference architecture

In an EON, the optical spectrum is divided into finer bandwidth portions called frequency slots (FS), where each FS consists of a fixed spectrum width of few GHz (e.g., 6.25 GHz or 12.5 GHz). A slice is understood as a group of FSs. The central frequency in a group of FSs determines where the assigned spectrum is centred. A slot granularity refers to the amount of FSs in a fibre, which relates to the FSs width. The portion of the spectrum assigned to a lightpath and characterized by its central frequency, number of slots and slot width is called a channel.

Recent advances in signal processing and modulation techniques which enable high-speed data stream using multiple lower-speed subcarriers with overlapped spectral positioning allow the effective optical spectrum use. Optical Orthogonal Frequency Division Multiplexing (OFDM) [11] and Nyquist WDM (N-WDM) [12], are the most common modulation techniques, both offering the same spectral efficiency and enabling flexible grid optical networks

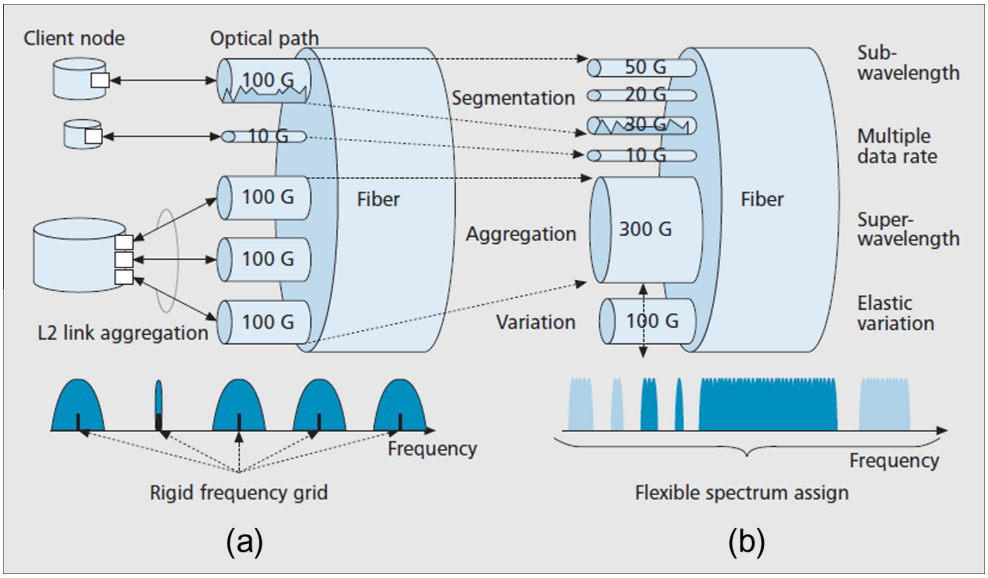

Fig. 1. Spectrum assignment: (a) in traditional WDM network; and (b) flexi-grid optical network [8].