SDN Based All-Optical Networks

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Abstract

In this paper, the concept of SDN based all-optical networks has been introduced. Nowadays, all-optical networks are known for their high-speed and large-capacity transmission. However, their management systems fail to obtain expected results. In case of some network changes, many devices have to be configured manually. To provide rapid reconfiguration in such circumstances, Software-Defined Networking (SDN) can be the solution. The idea of this approach is presented and its benefits and deployment are indicated.

Keywords: *All-optical networks, SDN, Software-Defined Networking, SDN architecture, virtual data centers, COSIGN, benefits of SDN, benefits of all-optical networks*

I. Introduction to All-Optical Networks

The all-optical network concept is transmitting an optical signal without transition to the electronic domain. The reason why we want to remain in the optical domain is that electronics are much slower, require more power and space, and additionally are less reliable than optics [1]. The main elements of all-optical networks are EDFA (erbium-doped fiber amplifier) or Raman amplifier and ROADM (reconfigurable optical add-drop multiplexer). EDFAs and Raman amplifiers allow eliminating electronic amplifiers whereas ROADMs become fundamental elements of optical switches that can perform port and lambda switching with wavelength conversion [2].

Despite many merits, all-optical networks have some drawbacks. The most significant of them is the lack of flexibility. Many things must be configured manually or by inefficient network management systems [3]. As we can read in [3]: *"... there is a need for an intelligent optical network. An intelligent optical network can realize the fast and flexible establishment of the connection and intelligent network control, the protection/restoration function, monitor signal performance for each wavelength and have an intelligent method to monitor all of the wavelengths, etc."*

Authors of [1] have similar thoughts claiming that: *"The next step in this evolution is dynamic networking, where connections can be rapidly established and torn down, without the involvement of operations personnel. Dynamic networking delivers bandwidth where and when it is needed, providing significant cost benefits to the enduser."*

Applying SDN Based All-optical networks is one of the possible solutions to resolve these issues.

II. Introduction to Software-Defined Networking (SDN)

Software-Defined Networking is a network concept of separating software from hardware. The two main components of SDN are Control Plane and Data Plane. While the former is responsible for managing different network components and configuring the hardware, the latter focuses purely on transmitting data [4]. Such a solution provides two primary benefits over the conventional network model. First of all, a network controller allows for high flexibility in network management. The administrator may use the controller's built-in apps to effortlessly configure network behavior, as well as they can create their programs to address corporate-specific issues. Furthermore, clear separation of hardware and software enables optimization of Data Plane [5]. As their only task is transmitting data, they should be able to do it quickly and efficiently in comparison to a standard network.

The protocol that most SDN-based networks rely on is OpenFlow. Its architecture ensures smooth separation and communication between control and data platforms [6]. One controller usually manages many network devices, whereas a single switch or router might be configured by a few different controllers. This solution contributes to scalability, safety and flexibility. Therefore, OpenFlow is perfectly suited to play the role of dominant SDN standard.

III. The theory behind SDN Based All-Optical Networks

In current telecommunication networks, it is crucial to enable rapid reconfiguration of network devices through remote management. It allows optimizing resource employment, to increase efficiency, resulting in minimized operational expenditure (OPEX). As a consequence, such networks can correspondingly fulfill changing business requirements [9].

Due to the development of software definition technology, the idea of combination SDN and all-optical networks appeared. The solution provides monitoring of the relevant parameters in the optical networks, flexibility, and adaptability in case of changes in the network. SDN lessens the configuration complexity of the control as well as the discrepancy between optical network equipment produced by different vendors [10].

The backbone of the approach is to control the forwarding plane through a centralized controller. SDN architecture in an all-optical network can be divided into four independent planes.

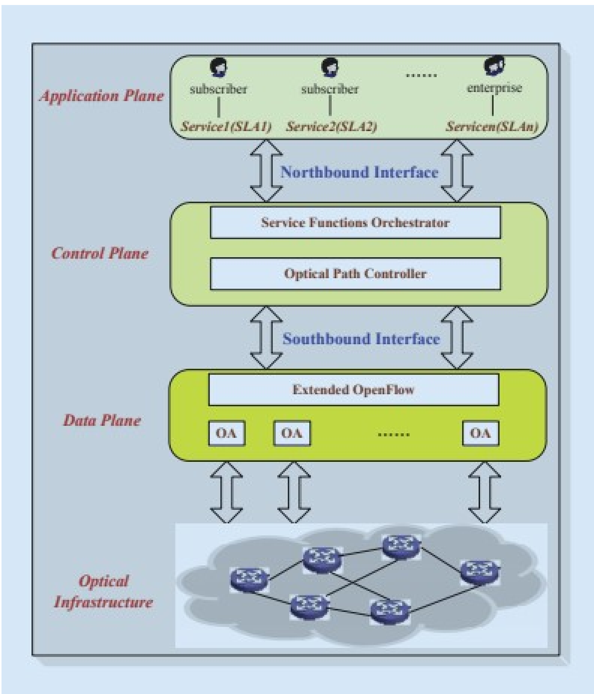

Figure 1: Structure diagram of SDN in all-optical network [11]

- **Application plane**

  Service-Level Agreement (SLA) between a service provider and clients defines requirements, which are transmitted to SDN controller by programs from the application plane [11]. These programs can create an overall view of the network based on data from SLA, such as service type, quality, and effectiveness. The connection between the controller and applications is realized by a northbound [12].

- **Control plane**

  The control plane manages the network traffic. The layer enables flexible access of the business model by the northbound interface (NBI) and homogeneous scheduling physical equipment by the southbound interface (SBI) [11]. According to the optical network topology and parameters of the equipment, the plane can incorporate and expand functionalities for requirements. Module controller estimates allocation of light resource, path, and wavelength.

- **Data plane**

  The primary function of the data plane is to handle the resource mapping of service instances and physical devices. It is accomplished by exchanging information between the OpenFlow protocol and OpenFlow Agent [11]. Enabling communication between the SDN controller and the lower level components is a southbound interface's responsibility [12].

- **Optical infrastructure**

  In the optical infrastructure, the particular light path construction and signal transmission are the physical devices accountable [11].

IV. SDN Based All-Optical Networks in real-world applications

Nowadays, network providers face the challenge of applying reconfigurable SDN based all-optical network solutions. Due to information globalization, our existing optical network architecture turned out to be increasingly harder to adjust to numerous novel technologies and applications [10]. Due to the development of many businesses relying on diverse cloud computing and big data solutions, the networks should follow along with the needs and meet the requirements of today's customers by providing a higher transmission rate and overall better quality. Furthermore, SDN helps with the cooperativity of optical network hardware offered by different vendors, which usually have their proprietary standards. Not only does this solution result in better compatibility, but also it is capable of decreasing the service expenses [11].

The previously raised issues about software-defined dynamic reconfigurability find its usability in the metro-access segment, where some researchers examined prospects of improving flexibility and adaptability at the edge of the network. So-called metro-access networks provide access networks traffic aggregation mainly from residential and business areas (point-to-point, point-to-multipoint links), especially 4G/5G mobile backhauling and connectivity between data-centers. Some parts of the network, for example, workplaces, can get overwhelmed at specific periods of the day, and on the contrary, can get empty at different periods [10]. That is the part where an SDN based all-optical network comes in. Considering SDN's centralized supervision, which manages the physical layer, fully aware of the entire network structure, this solution can dynamically allocate bandwidth, making it very flexible and adaptable to changes provided by up-to-date demands [10].

Another practical application where an SDN based all-optical network seems to be having an enormous impact in the future is Virtual data center(VDC) solutions

[7]. That mainly concerns better scalability and complexity of today's VDCs, simultaneously optimizing CAPEX and OPEX. Unfortunately, the latest technologies haven't provided relevant solutions, which could guarantee well-balanced fixed costs, particularly regarding energy consumption, connectivity, and capacity [13]. A merger between SDN and Network Function Virtualization (NFV) helps in solving some of these issues by the controlled scheduling of network resources. Created on-demand network resources make the process of scaling up much faster and more efficient. Such resource virtualization provides compatibility between heterogeneous optical hardware from various vendors. Furthermore, depending on business needs can demand an appropriate light path based on quality assessment [11]. SDN will be responsible for suitable and dynamic resource allocation over an all-optical physical substrate. Such future-proof VDC architecture consisting of managerial SDN and modern optical technologies form state-of-the-art solutions of tomorrow.

An example of VDC is proposed by The COSIGN consortium [13], which offers new data center architecture. Their project uses advanced optical hardware and Software-Defined Networking technologies. Its purpose is to bring solutions for future data center networks by improving their performance, scalability, management of the network, and overcoming existing and future bottlenecks of current methods.

The current implementation status of discussed technologies is still in a testing phase.

V. Conclusions

All-optical networks provide the most efficient way of transmitting data but they lack flexibility. On the other hand, SDN provides dynamic management required in today's constantly changing networks. SDN based all-optical networks combine advantages of optical infrastructure and the multiple possibilities of network management provided by SDN, resulting in high-speed, reliable, cost- and energy-efficient, and at the same time flexible networks.

Despite being still in a test phase, in the near future, such networks may be able to fulfill requirements of up-to-date demands generated by rapidly developing and dynamic services, which have to manipulate an ever-growing amount of data.

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