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A Review on Spectrum Sliced Elastic Optical Path Networks

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Abstract **Recent developments in the area of technologies, data center networks, cloud computing and social networks have caused the growth of a wide range of network applications. The data rate of these applications also varies from a few megabits/second (Mbps) to several gigabits/second (Gbps) for that reason increasing the burden on the internet. Best solution for this is to utilize the advancement in optical networks. In WDM network bandwidth up to 100Gbps can be utilized from the optical fiber in an energy efficient manner but its not efficient when traffic demands vary frequently. Spectrum sliced elastic optical path networks (SLICE) has been proposed as a long term solution to handle the ever increasing data traffic and the diverse demand range. SLICEs provide abundant bandwidth by enabling sub-wavelength, super-wavelength and multiple-rate data traffic accommodation in highly spectrum efficient manner.**

***Keywords*: EON, WXCs, OFDM, optical packet switching ,DWDM.**

I. INTRODUCTION

The web information activity has been developing at an enormous rate since it is start. The late developments in the regions of versatile advances, distributed computing and server farm systems have brought a colossal measure of rising applications alongside an enormous measure of information movement to web [1]. This exponential development in web activity represents an incredible intimidation to the hidden system framework and requires a more adaptable, lithe and strong foundation to bolster the future web movement.

The presentation of polarization division multiplexing, phase and multi-level modulation formats, coherent detection and digital equalization in electrical domain along with the advancement in optical amplification enabled long-distance dense wavelength-division multiplexed (DWDM) transmission with per-station transfer speed of 100 Gb/s. The extended distance, an optical signal can go through multiple DWDM links and wavelength cross-connects (WXCs) without undergoing optical-electrical optical (OEO) regeneration has made the optically routed networks feasible.

The optically routed networks have some significant points of interest, for example, elimination of OEO regenerators that are expensive, space and power-consuming and robotized remote provisioning of optical paths. In any case, the coarse allocation and the large granularity of the wavelength were major concerns in the realization of optical communication systems. The WRN requires full allocation of a whole wavelength to an optical path even when the traffic demand is not sufficient to occupy the entire capacity of wavelength (sub-wavelength traffic). Further, when the demand is more prominent than the capacity of a single wavelength (super-wavelength traffic), several wavelengths can be grouped together in a scalable manner [2].

However, adjacent wavelengths have to be separated by guard bands (GB), which can be in the order of several wavelengths. This may result in wastage of the expensive spectral resources. This led to the development of several other approaches such as optical packet switching (OPS), optical burst switching and waveband switching (WS) to meet the requirements of sub-wavelength and super-wavelength traffic accommodation. But these techniques lead to inefficiencies in bandwidth allocation.

To make more productive and versatile utilization of the spectrum, Spectrum-Sliced Elastic optical path (SLICE) networks or Elastic Optical Networks (EONs), or Flex-Grid networks has been proposed. By introduction of flexible granular grooming in the optical frequency domain the SLICE provide spectrum efficiency and scalable transportation of 100Gbps services.

II. SCALABLE OPTICAL NETWORKS

Several approaches have been proposed to provide the sub-wavelength and super-wavelength data transport in the optical domain

Waveband switching can be applied to reduce the port count of optical cross-connects (OXC) by switching a group of wavelengths together as a waveband using a single cross-connect port. Accordingly, a non-uniform waveband was proposed for an efficient accommodation of a wide range of traffic. This significantly reduces the count of the port number in OXC. However, wavelength demultiplexing requires that the adjacent wave lengths have to be separated by a buffer in the spectral domain. This leads to low spectral efficiency [2].

In optical packet switching (OPS) introduce packet transport concept such as multi protocol label switching (MPLS) and provider backbone bridge (PBB) in optical domain in order to take advantages of optical transparency, high efficiency due to statistical multiplexing and fine sub-wave length granularity [3].

In the OVC several wavelengths are grouped and allocated end to end according to the application request for bandwidth intensive and latency sensitive cutting edge applications. OVC was proposed for high end applications in order to provide an end to end capacity much higher than that of currently standardized interfaces, namely super-wavelength [4].

III. CONCEPT OF SLICE

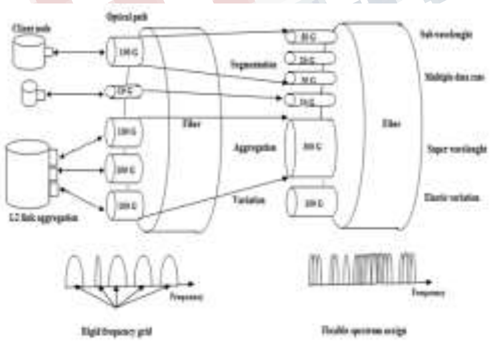

Fig1. (a) Conventional optical path network (b) SLICE (c) Spectrum assignment in SLICE

The aim of SLICE is to provide spectrum efficient and scalable transport of 100Gb/s services and beyond through the introduction of flexible granular grooming in the optical domain. The SLICE is an alternative to the immature optical packet switching technology and analogy of SDH/SONET concatenation of virtual containers, reducing the stranded bandwidth issue of conventional optical transport networks. In SLICE an end to end optical path is allocated a custom-size optical bandwidth by splicing the necessary spectral resources on given in network and light paths are expands and contracts in bandwidth size according to the traffic demand. The main features of SLICE are segmentation and aggregation of spectral resources and efficient accommodation data rates as shown in fig 1.

3.1 *SUB-WAVELENGTH TRAFFIC ACCOMMODATION*

WDM networks allocate an entire wavelength to a traffic demand even though the demand is not sufficient to fill the entire capacity of the wavelength (sub-wavelength traffic). This rigid and coarse assignment of wavelengths leads to an inefficient utilization of spectral resources. EONs allocate just enough sub-carriers to accommodate the traffic demand. Beside this, the granularity of the sub-carriers is very small as compared to a wavelength. This makes EONs a suitable candidate to handle the sub-wavelength traffic.

3.2 *SUPER-WAVELENGTH TRAFFIC ACCOMMODATION*

WDM networks allocate multiple independent channels comprising of a number of wavelengths for traffic demands that are greater than a capacity of a wavelength. However, the adjacent wavelengths have to be separated by guard bands (GB) and the size of GB can be in the order of wavelengths. However, in EONs, multiple contiguous sub-carriers can be combined to satisfy the specific demands. These sub-carriers are overlapping in frequency domain which further increases the spectral efficiency in EONs.

3.3 MULTIPLE DATA RATE ACCOMMODATION

In addition to sub-wavelength and super-wavelength traffic accommodation, EONs also enable spectrally-efficient direct accommodation of mixed data bit rates in the optical domain because of the flexible assignment of spectrum as. In contrast, WDM networks with fixed grid can lead to stranding of the optical bandwidth due to the excess frequency spacing for lower bit rate signals. In this way, EONs support various data rates including possible future ones in a highly spectrum-efficient manner [6].

client signal and n OTUk channels are transformed to the optical OFDM transmitter.

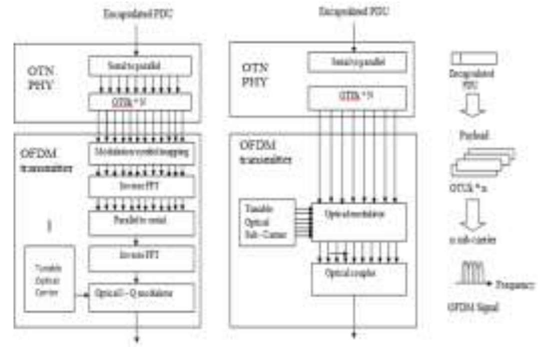

FIG.3. Implementation examples of OTN PHY and OFDM optics (a) Electrical approach (b) optical approach

IV. NETWORK AND NODE ARCHITECTURE OF SLICE

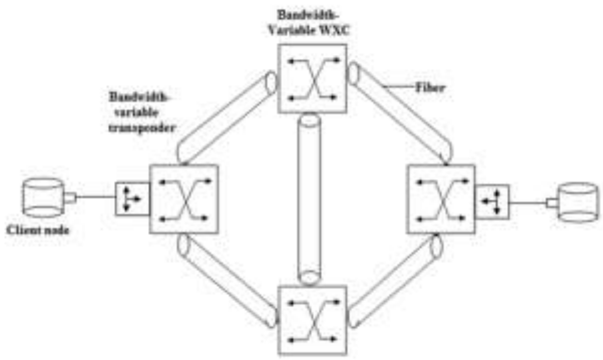

Fig 2 SLICE network model

SLICE consists of bandwidth variable transponders (BVTs) at network edge and bandwidth variable wavelength cross-connects (WXC's) in the network core. The Bandwidth variable transducer (BVTs) uses the appropriate spectral resource to transmit the optical signal to fulfill the traffic demand by minimizing separation between adjacent optical paths. Every Bandwidth variable wavelength cross-connect (BV-WXC) on the route from the source to destination allocates a cross connect within the size of the given spectral bandwidth. These technologies expand the switching window and raising the bandwidth of the elastic optical path.

V. SLICE TRANSPONDER MODEL

The SLICE transponder work in three operational modes, that is Frame mapped, Transport mapped and Direct mapped. The efficient utilization of network bandwidth by extracting the client protocol data units (PDUs) in the incoming client signal via client specific physical coding sublayer (PCS) and media access controller (MAC) layer and all idle client signal are removed. The PDUs are then encapsulated using generic framing procedure (GFP) and mapped onto n out of N OTUk channels in the optical transport network (OTN) frame. OTUk is an optical transport unit and k represent the supported data rate. According to the client traffic request the necessary bandwidth can be allocated to the client signal and n OTUk channels are transformed to the optical OFDM transmitter.

Orthogonal Frequency Division Multiplexing (OFDM) is used as modulation technique in optical networks. In OFDM, the data is transmitted over multiple orthogonal low rate sub-carriers with finer granularity. The main features of OFDM are spectral efficiency by allowing adjacent sub-carriers to overlap each other due to their orthogonal modulation and chromatic dispersion and polarization mode dispersion (PMD) of the transmission system can be effectively estimated and mitigated. This unique feature in OFDM enables the elastic bandwidth transmission by allocating a variable number of low-rate sub-carriers for a transmission.

There are two possible approaches to implementing OFDM in optics as shown in fig 3. In electrical approach data bits of n OTUk channels are mapped onto individual subcarriers and converted to the time series base band OFDM signal through inverse fast Fourier transform (IFFT) and digital to analog conversion. An optical OFDM signal is generated by linearly upconverting the baseband OFDM signal to the optical carrier frequency fed by a wavelength tunable laser using an optical in phase/quadrature (I/O) modulator. In optical approach an optical signal is directly generated by modulating the individual optical subscribers with data bits of each OTUk channel. The subscribers are subsequently combined with an optical coupler. In each case the optical frequency tuning and spectral bandwidth adjustment of the optical OFDM signal are achieved by changing the carrier laser optical frequency and adjusting the number of subcarriers.

VI. SLICE NODE MODEL

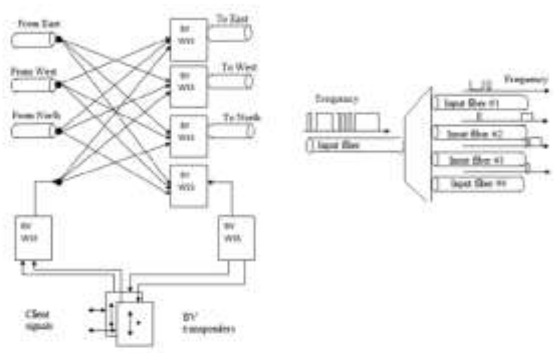

Fig.4. SLICE node model (a) Bandwidth variable WXC (b) Bandwidth variable WSS

The wavelength of the incoming and outgoing optical signal on the SLICE fiber node is maintained by self routing. The unique feature of the SLICE node is that the optical bandwidth of the self routing window is contiguously configured according to the spectral width of the incoming optical signal than the conventional WXC. WXC applications such as for example shown in Fig. 4a, for utilization of bandwidth –variable WSSs (BV WSSS) in broadcasting and configured to provide an function of add-and-drop for local signals as well as grooming and routing function for transit signals.

In general, using a WSS integrated spatial optics performs demultiplexing/multiplexing and optical switching function. Using the optical element (dispersive element) of the input fiber, the light is divided into its component spectra. Spectra unit separated spatially one-dimensional mirror array to focus on and be redirected to the desired output fiber. The Fig. 4b shown that the incoming optical signals with different optical bandwidth and center frequency can be routed to any output fibers. A bandwidth-variable WSS has also been realized by high resolution and high fill factor MEMS-based WSS [7].

VII. BENEFITS OF SLICE

7.1. Time-Dependent Elastic Bandwidth Sharing:

In SLICE, optical bandwidth can be allocated to different customers in a time based manner by adjusting the spectral bandwidth according to the complementary time dependent demand.

7.2. Energy Efficient Network Operation:

Energy consumption and efficiency is becoming a major concern for network operators during the periods of low link utilization, for example during the nighttime or weekend, SLICE transponders may partially turn off the electrical drivers through decreasing the number of OTUk channels and OFDM subcarriers. Also, the optical pumping power of the optical amplifiers on the route may be reduced to an appropriate level for supporting the client traffic. Both approaches will reduce the overall power consumption.

7.3. Bandwidth Squeezed Restoration:

In fixed bandwidth optical networks the failed optical path cannot be recovered unless the available bandwidth on the detour route equals or exceeds the original path. In SLICE the bandwidth of the failed working optical path is squeezed using expansion and contraction of SLICE in order to ensure the minimum connectivity.

VII. TECHNOLOGY CHALLENGES

High spectrum efficiency and scalability promise of the future in the case of optical transport networks, the SLICE concept presents new challenges. Network-level, flexible spectrum allocation planning, uneven spectrum allocation algorithm for routing and network monitoring and management plan, etc should be explored. In particular, the new bandwidth allocation scheme needs to be considered. Instead of a fixed allocation of ITU-T frequency grid currently used, the bandwidth allocation in SLICE carried out on the basis of the frequency of the slot. On the node level, novel optical switching and filtering element providing high resolution and steep filtering performance, efficient client protocol-data-unit mapping procedure, optimum modulation format for bandwidth variability and higher nonlinear impairment tolerance, should be developed.

VIII. CONCLUSION

The internet data traffic is expected to grow at an unprecedented rate in future. To handle the growth of date traffic in the future and to alleviate the issue of bandwidth crunch in the current infrastructure, this dissertation mainly studied the use and the application of EON.

SLICE is to provide spectrum-efficient and scalable transport services by using OFDM flexible rate transponders and bandwidth variable WXCs, cost effective fractional bandwidth services. The SLICE architecture enables sub-wavelength, super-wavelength and multi rate data traffic accommodations in highly spectrum effective manner.

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