Situational Analysis of Significant Research Contribution in Optical Network

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ABSTRACT
With the increasing demands of high speed internet and long-haul networking system, optical network has largely contributed in the area of network and communication system. Owing to lossless transmission and ability to carry massive data in a single optical fiber, optical networking has highly positive potential. It was seen that this topic is consistently being an active research area from last decade, however, there are certain trade-off being seen in the research techniques too. The prime aim of this paper is to furnish some unique and potential information recapping the effectiveness of the techniques introduced in research area by extracting the open issues in optical networking system. The compact version of the article will be definitely assist and encourage the upcoming researchers as it furnishes some constructive technique for adopting soft-computational approaches of investigation the problems.

Keywords
Optical Communication, Network, Wavelength Routing, WDM

1. INTRODUCTION
Optical networking systems are the new revolution in networking principles that permits connectivity to large distance communication system. In the conventional networking systems, the electrons carry the data, where it has limitation to carry only certain bytes of data. However, optical network works on the principle of light, where each smaller units of lights termed as photon have the capability to carry massive and more bulky data [1]. In this regards, optical network is quite faster than conventional networking system as photons are lighter weighted as compared to electrons. Moreover, compared to electrons, photons have maximized frequency level and thereby it has minimal size of wavelength, for which reason, it can carry maximum size of the data packets in its networking system. The possible advantages of adopting optical networking systems are as follows:

1.1 Minimal Loss of Transmission
Majority of the optical networks uses design of optical amplifier with ultra low loss fibers and highly advanced silica fibers causing no loss of data packets during transmission.

1.2 Supportability of Higher Channel Capacity
As per the networking principle, the carrier frequency for the signals being transmitted is directly proportional to the channel capacity of the communication system. The range of frequency used by optical network is 10^{13}-10^{15} Hz that results in higher capacity of the channel compared to the traditional networking system.

1.3 Higher Security
As the optical fiber is physically secured by padding system, hence there is no probability of any radiation of the photons during transmission. Moreover, owing to different signaling properties of photons, it is nearly impossible to tap the signals.

1.4 High Quality Signals
Conventional networking system suffers from interference as well as other external factors like scattering, fading, etc. But optical networking system uses fibers made from glass for which reason external environmental factors have least impact on the signal transmission. It can be used in most adverse condition where traditional networking system fails.

Optical network works on the principle of point-to-point topology, curb-switch network, and passive optical network. various important components in optical networks are i) transmitter, ii) multiplexer, iii) Demultiplexer, and iv) Optical switches, and v) Optical Amplifiers. An optical network increasingly uses wavelength division multiplexing (WDM) that is responsible for performing multiplexing of various optical signals of multiple wavelengths into a unit channel. In order to do multiplexing, the system is also dependent on using switching technologies [2]. One of such significant switching technology used in optical networking is wavelength selective switching (WSS) that uses several of switching arrays to direct the switched signals among the optical fibers based on the specifications of the wavelengths [3]. A significant form of multiplexer used for this purpose is termed as reconfigurable add-drop multiplexer (ROADM) that provides the network with capability of remotely switching the optical traffic from WDM system [4]. Other types of multiplexing techniques include Time-division multiplexing [2].

Although optical network is increasing being used, but owing to inclusion of various hardware (switches, splitters, routers, amplifiers), the research community is encountering a bigger set of challenges as analyzing optical network from soft-computational viewpoint is quite challenging. Although optical network have some significant potential features, it has its constraints too, which is hard to explore. Owing to completely different operational principles and signal processing, the conventional signal processing algorithms finds few scopes in performing in-depth investigation. Hence, this paper briefly performs situational analysis of the existing techniques and makes some constructive suggestion for upcoming researchers to consider for adopting better computational modelling of optical network.

2. RESEARCH ISSUES IN OPTICAL NETWORK

Although, majority of the theory exhibits superior functional properties of optical network, but there are few loopholes too. The significant issues of Optical Network that is found to be constantly addressed by researchers are:

2.1 Topological Problem

Conventional networking topology is quite easier as various standards do exits. But optical networking systems are not that easy. It is very challenging task to evolve up with design principle to carry out IP based traffic connecting the various optical IP routers. Even performing the routing of this design principle on physical topology is quite challenging even in presence of traffic information as well as physical topology.

2.2 Routing and Wavelength Assignment Problem

This problem is also called as RWA problem in optical network and various literatures till date are still finding challenge to overcome it. RWA issues needs to extract the links of physical media for constructing individual lightpaths and direct the lightpath in the direction of physical topology. Assigning the wavelength in each lightpath requires a complex system for each physical link, which is expensive in nature.

2.3 Issues in ROADM Design

ROADM also called as Reconfigurable Add Drop Multiplexer allows remotely configuring any wavelengths at any optical nodes. It is frequently considered in design principles as it furnishes reliable networking and manages channel capacity uniquely. However, in last 5 years, there are only 40 significant literatures addressing the issues of ROADM, which is very less. Such design of ROADM is seen suffering from constant assignment of wavelength, constant assignment of direction, and conflicts of significant wavelengths.

3. PROBLEM IDENTIFICATION

In the area of optical network, if the system performs consideration of the complete conversion of the wavelength, than a call is only accepted if there is an availability of atleast one free wavelength [5]. However, if the wavelength translation is not considered that also a call can be accepted on a path if there is an availability of one wavelength that is free on all the link of that route at same time. This is one of the challenging tasks in the optical networking theory and is termed as wavelength continuity constraint [6]. We identify this problem as we are interested to explore large number of unfavorable conditions that acts as an impediment to perform an effective routing in optical network. The contradictory in this principle is that there is a higher probability of blocking a call even if there is an availability of free wavelengths on all the hops. Hence, it is evident that complete conversion of wavelength can be beneficial for reducing the blocking probability. Unfortunately, this logic was not seen to be addressed in literature and hence such research gap has to be further investigated imposing as a challenge for future research work. All the wavelengths being used in the optical network are required to be monitored for choosing the correct operation, which is another problematic issue especially in a situation, where the traffic behaviour is highly uncertain. Hence, operation cost goes higher by using higher number of hardware devices for growing requirements. The existing system calls for pre-assigning as well as adding up new services but it also requires a network manager to perform redesigning of the ROADM model, which is not only time consuming but also not reliable. It may pose various types of disruption in traffic. In present situation, majority of the ROADM system spontaneous monitor OSNR, where the emphasis is mainly on tracking power so that network engineers can ensure optimal quality of signal. Unfortunately, in this scenario, majority of the wavelength will require a better amplification as well as the every wavelength to be added or dropped must be hardwired to specific client port (WSS). This design principle of ROADM will actually narrow down the capabilities of ROADM to mitigate massive client request resulting in spectral narrowing, polarization dependent loss at same time. Owing to this issue, the ring size diminishes and eventually calls for higher quality of receivers and transmitter with enhanced capabilities. Even if such sophisticated hardware were adopted, then also it can it cannot solve the problem of performing communication through unknown wavelengths and client's devices. However, open problems are that i) majority of the ROADM is still expensive and design is highly complicated with inconsistencies in the traffic management schemes, ii) Majority of the ROADM models are still not considered as best solution for either ring or mesh based connection in optical networks, and iii) the presence of OBS ensures better granularity in wavelengths, but it doesn't permit provisioning of sub-wavelength as well as network flow management of traffic. The problem becomes much worst, when the traffic is associated with uncertainty of request from user in optical network.

4. PRIOR STUDIES

There are massive set of research papers witnessed in the area of optical networks. Peng et al. [7] have investigated about traffic behaviour in optical network and analyzed their outcomes with blocking probabilities. An analytical framework have been presented by Xin [8] focusing on dynamic grooming of traffic. Their framework was found to support multiple and discrete rates of data on both logical as well as physical links. Investigation towards positioning of nodes in optical network was witnessed in the work done by Shen et al. [9]. Problems of scheduling were closely studied by Figueiram et al. [10] on multi-path optical network. The author have studied the nature of the request arriving in the traffic and investigated some potential traits in traffic request. Similar problem was also addressed by Lee et al. [11]. A prototype of ensuring better connectivity in the optical fiber was introduced by Nakajima et al. [12]. The prototype was also claimed to support next generation optical network. Exclusive studies toward passive optical network can be seen in the work carried out by Tian et al. [13]. The study has considered WDM (Wavelength-Division multiplexing) and signal modulation technique to enhance the performance of the signals. A generic version of wavelength routing was designed by Zhang et al. [14]. Work towards prioritizing the wavelength is carried out by Soares et al. [15]. The author has proposed architecture to perform partial conversion of wavelengths.

Usage of micro ring resonator for the purpose of generating massive channel capacity was seen in the study of Yupapin et al. [16]. The author has used key distribution mechanism on optical router to signify the wavelength estimates. Study towards wavelength assignment was carried out by Lee et al. [17]. The study has proposed architecture exclusively for multiple types of wavelengths in passive optical network. Unique study was seen in the work of Luo et al. [18] where the optical network has been integrated with cloud computing. An extent of good mathematical modelling was seen in the

study of Chau et al. [19] who have focused on addressing constraints for wavelength add/drop. Works done by Gianluigi et al. [20] have focused on the scalability issues of wavelength selective switching. Roy et al. [21] have adopted traffic grooming for investigating the multi-layered switching. The outcome was found to enhance the spectral efficiency. Karamitos et al. [22] have used least mean square technique for performing reservation of resources in optical burst switching. Miller et al. [23] have focused on spatial ROADM model and used advance interferometers to solve it. Ansari et al. [24] have used arbitrary assignment of wavelength to solve the issues of blocking probability in optical networking. Jasmine et al. [25] have adopted feedback based routing technique to solve the routing issues in optical network.

5. OPEN ISSUES / SUGGESTIONS

There are substantial amount of literatures that has been introduced in the last decade for enhancing the network performance of optical network. The information of the prior work discussed in prior sections highlights some of the significant studies that have been carried out explicitly for ROADM and Blocking probability study in optical network. However, closer looks into the work are found with following issues:

- Less consideration of the real-time constraints in optical network.
- Relying on conventional ROADM with significant issues of optimization still unaddressed.
- Usage of expensive hardware or proprietary tools posing a natural limitation of narrowed evaluation.
- No consideration of real-time uncertainty in traffic behaviour been even considered or attempted to model.
- No significant or extended modelling technique to ensure optimal routing in peak traffic condition.
- Traffic based modelling based on OSNR, ROADM, WSS, and probability theory was never attempted before.

Hence, the above points are some of the significant open issues, where still various researchers are found to be struggling to evolve up with novel ideas. In order to overcome such issues, it is required that a researchers should try out with a simple modelling of ROADM architecture as it is a common myth that ROADM architecture is highly standardized and is difficult to be amended. Hence, if the simple architecture is designed, it will open the doors of solution for various problems. It will be feasible to perform certain significant and serious computational model, if existing ROADM model is revised. Moreover, there is a critical need of mathematical modelling considering the problems of wavelength routing assignment as well as other quality of service issues in optical network. The mathematical model should also be designed in such a way that it should cater up the real-time requirements of the optical network. Finally, a better benchmarking policy is required. It was seen that work done by Lacra Pavel [26], [27], and [28] have make some good milestone in the research. There work was found to be significantly cited by many researchers and can be considered as available benchmarks. Hence, the upcoming research work could target to perform comparative analysis of the proposed system with such available benchmarked studies. Hence, following suggestions are being made for the upcoming researchers:

- Getting a good base paper is most difficult and time consuming task. Every research work starts by final identification of certain benchmark studies in the problem domain. In the area of optical network, there are various IEEE journals that focus on mitigating the issues. Majority of the mitigation process is less soft-computational viewpoint. Hence, it is strongly suggested that researchers should consider the work done by some available benchmarks e.g. Lacra Pavel [26], [27], and [28] and further re-formulate their problems.
- The researcher should aim to design a computational framework that can map the actual scenario of optical communication system considering different types of traffic considering the real-datasheets of the existing hardware. This pattern of investigation will save considerable amount of time to initialize the appropriate values of the variables, while carrying out simulation studies.
- The researchers must focus on designing a case study of heavier files (e.g. Multimedia digital content) as experimental input factor to analyse the traffic load in simulated optical communication system thereby formulating a queuing network model.
- The researchers must tune up the multiplexer using Reconfigurable Optical Add/Drop Multiplexer (ROADM) for the purpose of optimizing the load on optical communication system.
- Finally, the researchers must aim to perform dynamical routing, blocking and attenuation of all WDM wavelengths within a network node using Wavelength Selective Switch (WSS) along with ROADM.

6. CONCLUSION

The prime objective of this study is to briefly discuss about the area of optical network. The paper has jotted some lines about the significant technologies, components, and issues encountered by the existing area of optical network. The paper have also discussed some of the most recent works being carried out by the researchers till date along with the discussion of research gap in the existing study. The paper finally makes some suggestion as a contribution to the upcoming researchers for considering while performing novel investigation in the area of optical network. Our future work will be on the direction of evolution of simple and novel mathematical technique that will use ROADM for the purpose of modelling the uncertain traffic condition in optical network. Apart from OSNR, our future study will also adopt various other performance parameters e.g. throughput, packet delivery ratio, BER, blocking probability etc. The prime objectives will be towards i) evolution of an algorithm for better traffic management, ii) coming up with new ROADM implementation with enhanced charecteristics, iii) adoption of OBS and WSS for the purpose of improving the switching operation of the optical network. The evaluation of such study will be carried out by transmitting real-time files through optical node in presence of uncertain traffic and evaluate its performances based on the above mentioned strategies.

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